This report presents a collection of papers on the past and present concepts of the hospital environment and the principles for establishing and carrying out control programs. It is volume I of a series of publications with the overall title, "Environmental Aspects of the Hospital," developed as a joint project of the Division of Hospital and Medical Facilities and the Division of Environmental Engineering and Food Protection of the Public Health Service. The papers in the series were prepared by authorities who have extensive experience in their specialties, with particular reference to medical facilities.

ENVIRONMENTAL ASPECTS of the HOSPITAL

volume I INFECTION CONTROL

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Division of Hospital and Medical Facilities and
Division of Environmental Engineering and Food Protection
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foreword

This publication is the first in a series being produced to provide guidelines for those responsible for developing environmental control programs in the modern hospital. Special attention is given to the major considerations for each department head in carrying out his part of such programs. An effort has been made to present a synthesis of principles and practices derived from successful environmental control programs in hospitals.

As in most areas of technology today, those who are privileged to work in hospitals are aware of many more solutions, both medical and administrative, than are being applied. The papers in this publication, prepared by recognized authorities, do not attempt to define exact solutions, and should not be regarded as criteria to be uniformly followed in every hospital. It is hoped that they are sufficiently meaningful, however, to provide the broad framework upon which specific solutions determined by local circumstances and resources can be applied.

The Committee on Environmental Engineering Aspects of Hospitals and Medical Care Institutions, listed on the following page, served as the review and advisory group on the content of the series.

This volume outlines the history and present status of the modern hospital both as a health center within the community and as a clinical setting for the practice of medical specialties. The principles of bacteriology and epidemiology are presented as additional background for discussion of infection control procedures and the basic considerations in the decontamination and sterilization of equipment, supplies, and the general environment.

Subsequent publications will deal with the supportive departments, safety programs, and administrative aspects of the environmental control.

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contents

FIGURES

FIGURES—Continued

CHART

TABLES

Chapter I

PUBLIC HEALTH ASPECTS OF THE HOSPITAL

Robert L. Schaeffer

The direct relationship of medical care facilities to public health programs has never been as pronounced as it is today. The medical community with its traditional independence has never made broad medical application of the word "public" except in the areas usually termed preventive, as contrasted to curative, medicine. Preventive medicine, as reflected in sanitation programs, communicable disease case finding, therapy and immunization programs, was for a century the heart of the public health movement. These preventive efforts were augmented by private physicians at the patient's option, usually for treatment following the diagnosis of a communicable disease, or for children's immunization in the era before school health programs and maternal and child health clinics were widely available. Curative medicine was generally provided at facilities staffed and directed by private physicians. Patients were admitted by physician referral, and physician and hospital fees were paid directly by the patient. The voluntary hospital furnished little public health care, except for the welfare patient, until after World War II.

The development of medical insurance programs on a broad scale, followed by the initiation of the Hill-Burton program [1] in 1946 marked a new era in hospital construction and significance. The hospital became, more than ever, a social as well as a medical institution on the American scene.

A brief historical summary of hospital growth, a review of some areas of dramatic expansion, and a few examples of the hospital's current interrelationship with public health programs follow.

THE EARLY HOSPITAL

Because of the smaller number of urban areas requiring medical care facilities, hospitals in the United States were comparatively slower in establishment and growth than their European counterparts. The early institution, under either church or governmental sponsorship, gave way in England to voluntary institutions supported by private subscriptions and endowments. The American pattern followed the English, with the establishment of general hospitals such as Pennsylvania Hospital in Philadelphia in 1751, and New York Hospital in 1791. Benjamin Franklin served as sponsor for the Pennsylvania Hospital, proposing that it be supported by a scheme of matching funds from both private subscriptions and public monies appropriated by the State Assembly. Franklin drew the bill for the Assembly with a conditional clause specifying that if private subscriptions for capital stock reached 2,000 pounds, the Assembly would match the sum. This provision was the key to passage by a previously reluctant legislature, as Franklin recorded:

> This condition carried the bill through; for the members, who had opposed the grant, now conceived they might have the credit of being charitable without the expense, agreed to its passage, and then, in soliciting the subscriptions among the people, we urged the conditional promise of the law as an additional motive to give, since every man's donation would be doubled; thus the clause worked both ways.

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The subscriptions accordingly soon exceeded the requisite sum, and we claimed and received the public gift, which enabled us to carry the design into execution.[2]

Until the beginning of the 20th century, American hospitals were similar to those in Europe—places to care for the medically indigent, usually terminal cases. There were pest houses for isolating cases of smallpox, yellow fever, and cholera. Dispensaries were established to distribute medications to the indigent, and served as training grounds in diagnosis and pharmacy for many of the pioneer physicians. These early dispensaries were the precursors of the outpatient care facilities of modern hospitals. In these early years, American hospitals had a public reputation as places where people went to die. The well-to-do were cared for in their homes, a reflection of status as well as a practical response to the primitive nursing care and appalling mortality rates in the hospitals.

The dramatic expansion of population centers, caused in part by the influx of immigrants from [illegible], led to the deplorable conditions described by Griscom[3] in 1845, Shattuck[4] in 1850, and Stephen Smith in 1865. Smith's statement on the conditions in New York City at the close of the Civil War reflects the increasing awareness of need for public health programs:

> And when we remember that the great excess of mortality and of sickness in our city occurs among the poorer classes, and that such excessive unhealthiness and mortality is a public source of physical and social want, demoralization and pauperism, the subject of needed sanitary reforms in this crowded metropolis assumes such vast magnitude as to demand the most serious consideration of those who have regard for the welfare of their fellow beings, and the interests of their community.[5]

Population increases, predominantly in the laboring classes, led to greater use of American hospitals, although overcrowding increased the dangers to which patients were exposed. Until the middle 19th century, surgery was limited both by the terrible mortality rates from postoperative sepsis and the very limited means of controlling pain. The first use of ether in 1846 helped solve many of the problems of surgical procedures. The beginnings of hospital sepsis control did not appear until Lister, building on Pasteur's bacteriological work in the fermentation process, introduced the concept of "antiseptic" surgery in the 1860's. Semmelweiss and Holmes, while widely condemned by their colleagues before the post-Civil War increase of bacteriological knowledge, were eventually recognized as pioneers for their work on puerperal sepsis reduction.

The general impetus to sanitary reforms was given by the great outbreaks of yellow fever, cholera, and typhoid fever. The discovery that removing garbage and waste from city streets, installing sewer systems, and improving the sanitary quality of drinking water could dramatically lower the incidence of epidemic disease, antedated the so-called "bacteriological era" by some two decades. Speaking of the practical results of the "filth" control theory as to both its effects on epidemic reduction and better environmental control, Welch has said:

> It is doubtful whether any more useful working hypothesis concerning the sources of epidemics could have been framed in 1848 than that which guided most of the sanitary activities at that period and for many subsequent years, erroneous as it was and tenaciously as it was held after it has served its primary purpose. . . .
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> * * * * *
>
> The acceptance of this theory led to a campaign . . . for "general cleaning up." Thus were laid the essential foundations of modern sanitation of the environment, and much of the routine technique of the present-day health officer . . . was established in this early period.[6]

The Civil War hospitals, although operated before Lister's procedures of antiseptic surgery were either published or accepted, taught valuable lessons in medical care. Chief among them were conclusive demonstration of the value of anesthesia in reducing shock and suffering, and the benefits of employing trained female nurses in caring for the sick. New consideration was given to the patients' diet, initially through including fresh vegetables on the menu to reduce scurvy. Until this time, there had been no popular recognition of scurvy as a dietary deficiency disease, despite Lind's famous "limejuice" experiment in the British Navy in 1747, and Buchan's efforts to control scurvy in the 1830's when he added fresh fruit and vegetables to salt meat diets.

THE BACTERIOLOGICAL ERA

Lister's theories, published between 1865 and 1867, laid the foundations of medical bacteriology and surgical asepsis. Supported in succeeding years by the work of Davaine on septicemia, by that of Koch on the disease processes of anthrax, tuberculosis, and cholera; by Eberth's work in typhoid fever and that of Pasteur in rabies, the age of bacteriological investigation was well begun. The increasing knowledge of microbiology gave rise not only to changes in surgical technique but to greatly expanded interest in sterilization and disinfection processes. At the first meeting of the American Public Health Association in 1872, Elwyn Waller presented a paper on disinfection, outlining the usefulness of "arresting decomposition" with carbolic acid, creosote solutions, mineral salts, and thymol. At the same meeting, Dr. Barnard of Columbia University discussed "The Germ Theory of Disease and Its Relations to Hygiene." In 1878, A. H. Johnson published an article entitled "Disinfectants for Scarlet Fever," in which he suggested the use of high temperature (steam or dry heat), nitrous oxide, ozone, chlorine gas, and sulfur dioxide.[7]

Sternberg evaluated the use of disinfecting agents, recommending destruction of sporogenous organisms by steam under pressure, mercuric chloride, or boiling water. Fumigation was looked on as virtually indispensable for terminal disinfection. A report of the American Public Health Association published in 1888 described methods for bedding and clothing fumigation, principally by sulphur dioxide gas. After the advent of formaldehyde in the middle 1890's, this gas was the agent of choice until about 1910 despite some health officers pointing out the needless expense and scientific futility of fumigation as it was then practiced.[8] Some attempt was made to combine formaldehyde and steam to assure adequate penetration by the disinfectant, but results were still unreliable and the method was eventually discredited. Notable advances in developing pressure steam sterilization equipment, made by such workers as Bergman, Sprague, and Underwood between 1886 and 1915, established this method as the standard means of sterilizing most hospital instruments and materials.

THE MODERN HOSPITAL

Paralleling the increase of hospitals from less than 200 in 1873 to the 1964 census of over 7,000, there have been sweeping changes in both the medical and social forces which shape the hospital's role in serving the public. Davis[9] defines the major developments in the hospital under seven headings:

1. Extension of functions, so that the hospital has become the central agent of society for assembling and organizing medical knowledge and technology for the service of the people
2. Expansion of hospital clientele
3. Extension of the role of local, State and national governments in hospitalization
4. Increase in costs of hospitalization
5. New sources of hospital income
6. Dominance of private professional practice in the general hospital
7. Development of methods of appraising and promoting quality of care

The first two points have been the principal causes for the remaining five changes.

With the use of anesthesia, the advent of the "Bacteriological Era," and the beginnings of aseptic controls, both the specialist and the general practitioner required more facilities and equipment than ever before. MacEachern has pointed out:

> As the nineteenth century neared its close, surgery was becoming so frequent in hospitals that the very word "operation" was to the lay mind almost synonymous with "hospitalization." But a new hospital function, care of communicable diseases, was in process of development, promoted by the wealth of bacteriological discoveries then taking place. . . . Study of the etiology of these diseases required laboratories. Treatment of patients with some of the infections necessitated isolation. The hospital was the logical place for observation of communicable diseases.[10]

A significant change was also reflected by the growth of obstetrical services, one of the most pronounced expansions of hospital functions. Before hospital services became the first resort for serious illness and major surgery, nearly all women were delivered at home, except those unfortunates who were completely alone or destitute. Despite the work of Semmelweiss and Holmes in demonstrating the hazards of sepsis in childbirth, at the turn of the century the mother's natural resistance, the thoroughness of her attending physician in pre-

paring the home environment, and blind chance, determined her survival. As both the quality and volume of care improved and greater safety was achieved in the hospital setting for both mother and child, obstetrical services shifted from the home to medical care institutions.

Diagnostic laboratories began as adjuncts to health departments rather than hospitals. The New York City Bacteriological Diagnostic Laboratory was opened in 1892 by Dr. Herman Biggs who equipped two tenement rooms on Mott Street with laboratory equipment. Dr. Biggs was employed both by the New York Health Department and by Bellevue Hospital, where he had taken his training. The outbreaks of cholera in Hamburg, Germany, in August 1892, and the danger of importing it from ships docking in New York led Dr. Bryant, then the City Commissioner of Health, to establish a division of bacteriology and disinfection with Dr. Biggs and his tiny laboratory as its focal point. The Massachusetts Health Commissioner, Dr. Henry Walcott, organized a State laboratory to produce diphtheria antitoxin in 1894, and Dr. B. M. Bolton established a laboratory in Philadelphia to aid in diphtheria control in 1895. The laboratory was included among standard hospital services in succeeding years, and was equipped with such improved diagnostic tools as the X-ray (1896), the electrocardiograph (1903), and in the next 5 years, basal metabolism equipment, the Wasserman test, pancreatic function and urinary sugar tests, and the fluoroscopic screen. The increasing use of organized skills and specialized apparatus enabled the diagnostic laboratory to aid in treating diseases previously thought incurable, thereby bolstering public confidence and increasing hospital use.

Improved therapy in many areas had a concurrent effect on expanding the use of medical care facilities. The relationship of diet to disease prevention was better defined by such workers as Finley in demonstrating the effect of diet on the prevention of rickets, and by Goldberger's studies on pellagra. Vitamin research by Hopkins, Fund, and McCollum opened other therapeutic avenues in the field of nutrition. The role of the hospital in diet therapy became far more significant than maintaining a dietary facility simply to feed the patients. MacEachern characterizes the modern hospital's role as follows:

> The hospital is indispensable in many forms of diet and glandular therapy, not because administration requires special equipment, but because accurate diagnostic tests must be made before, during, and after treatment. Metabolism tests, fluoroscopic examinations, tests of heart function, blood analyses—all require special apparatus and specially trained personnel.[11]

Improved nursing skills also carried weight in changing the patterns of hospital use. From a total of some three dozen nursing schools in 1890, the number rose to over 1,100 by 1910. Training changed significantly from the inservice, work-and-learn system that furnished low-cost service first, and "training" second, toward the more theoretical and scientific training that reflected the greater complexity of medical skills as well as the nurse's expanding role in medical care.

Two remaining major changes in the hospital and its public health functions appeared in the early years of this century: The rise of medical specialization, with its pursuit of research in the hospital setting, and the appearance and growth of outpatient and emergency departments.

The new diagnostic, medical, and surgical techniques, as they became increasingly complex and as new skills were added, led inevitably to specialization. From the latter 19th century, when the term "physician" was inclusive and discrete, the practitioner gradually became a specialist in bacteriology, radiology, obstetrics, any one of several types of surgery or internal medicine, and eventually an individual of great competence in one of the dozens of fields presently listed by professional certifying boards.

Inevitably, as more was learned in given areas, more needed to be learned. Research carried out in facilities equipped for diagnosis, clinical observation, and measurement, and staffed with an array of professional personnel capable of applying, observing, and recording the effects of new techniques, made the hospital a natural focus for efforts to advance the state of medical knowledge. Not only in university hospitals as a necessary part of physician's training, but in the larger general hospitals across the country, research became a major concern.

Public demand for more comprehensive hospital care played a dominant role in this increase of specialization and research. The popular notion developed that good care for any sort of ailment required a specialist. The family physician was viewed increasingly by his patient as a medical screening resource for serious ailments, and except

for the most urgent initial care, was expected to refer his patient to a specialist for complete diagnosis and treatment. This viewpoint has also carried its penalties for the public in higher medical fees and more elaborate and lengthy procedures than were necessary when medicine was a simpler and less exact science.

The pressure on the private physician and the hospital to treat patients who were both ambulatory and indigent, or so represented themselves, reached a point where organized, properly equipped, and reasonably fast diagnosis and treatment for these individuals had to be provided without unnecessary inpatient care. At first, the outpatient facility was largely undifferentiated, handling medical, orthopedic, pediatric, and dental functions on a case-by-case basis. Gradually the functions became broader and more numerous, and at present, regularly scheduled outpatient clinics may include the following specialized services:[12]

a. Allergy	k. Mental hygiene
b. Cardiovascular	l. Neurological
c. Chest	m. Orthopedic
d. Dental	n. Pediatric
e. Dermatology	o. Postpartum
f. Diabetic	p. Prenatal
g. Ear, nose, and throat	q. Screening
h. Eye	r. Surgical
i. Gynecology	s. Urology
j. Medical	

Just as the dispensary furnished both a needed public facility and a fertile training ground for 19th century physicians, so has the outpatient clinic come to provide needed care for ambulatory cases, both before and after hospitalization, bringing indispensable diagnostic experience to many practicing physicians and nurses.

The explosive growth of the emergency department, especially since World War II, from its early mission of treating victims of street accidents to handling an increasing variety of complaints, marks another extension of the hospital's function into community health practice. When private practitioners and specialists became so grossly overworked that a rigid office appointment schedule was literally their only means of survival, the people began to take an increasing number of their ailments to the emergency and outpatient departments. Admittedly, some "emergency" cases today may not be deserving of such handling from a medical standpoint; but to the average citizen an ailing child, a home injury, a febrile respiratory complaint of sudden onset, understandably suggest immediate attention rather than a physician's office appointment a day to several weeks away.

Stewart T. Hamilton, M.D., summarized the physician's viewpoint as follows:

> It is more convenient and better medicine for him [the physician] to meet his patient with an emergency at the hospital rather than in his office. Lack of availability of the physician is a factor, of course, as evidenced by emergency department peaks at times when doctors' offices are closed, but this, too, is not the main reason. The main reason for these visits to emergency departments stems from increasing general acceptance by the physician and by the public of the hospital as the community health care center.[13]

It is this great extension of what the hospital does that has changed it from a facility for a relatively few individual cases to a complex institution accommodating a high proportion of all community residents. They are admitted for needs ranging from major surgery through diagnostic screening of all descriptions, to the treatment of head colds and relief for baby's colic.

It is equally evident that the scope of coverage and numbers of patients treated today make the hospital a dominant force in community medical programs. The responsibilities of the modern medical care center include the functions of the entire medical field, its clientele, and the whole population in the area served. The clinical-preventive differentiation between hospital programs and community public health programs brought about by the era of specialization still continues, but the degree of difference is constantly becoming more difficult to define. Health testing programs for tuberculosis, venereal disease, diabetes, and glaucoma; polio and influenza vaccination programs; and maternal and child health clinics, to mention a few examples, are most frequently hospital centered, using the facilities and equipment of the institution rather than separate health department clinics or private physicians' offices.

Since the bulk of government hospital ownership is concentrated in mental health facilities, the increased public health function of the general hospital has resulted mainly from a change in the philosophy of voluntary institutions. The major impact on the hospital by government has been through extension and support of facility build-

ing under the Hill-Burton program. At the local level, the creation of hospital planning councils, often under local governmental auspices, is intended to better distribute available medical care and minimize duplication of hospital services.

Prepaid medical care has had an enormous impact on the volume and scope of hospital use. Stabilization of hospital financing and reduction of welfare patient care deficits have enabled hospitals to afford specialized skills and equipment the public expects. Surprisingly, despite new construction programs and prepaid insurance, there has been virtually no net increase in the hospital bed/population ratio since the late 1940's.[14] New construction has merely kept pace with the Nation's population increase, while better distribution of services and improvement in the quality of care have constituted the most significant advances. Average length of stay in the hospital has decreased somewhat, indicating that while the number of patient days per 1,000 population has declined, admission rates, particularly in the short term general hospital, have increased.[15]

THE HOSPITAL ENVIRONMENT

All factors indicate that more people are using the hospital than ever before, benefiting from an unparalleled rate of progress in medical knowledge while being unavoidably exposed to whatever environmental hazards exist within the institution. Patients, staff, and visitors certainly do not always bring an infection with them into the hospital, but if one is contracted within the institution they do not always leave it behind when they reenter the community. Many of the remaining chapters of this publication will illustrate in more detail the factors affecting the epidemiology and control of hospital infections.

Two principal points recur throughout the text:

- First, the interdependence of epidemiological factors and the lack of precise definition of the effect of many environmental contaminants does not permit any single standard procedure to prevent infections. Good infection control depends on an endless and thorough application of principles, any or all of which may be controlling in an individual case. In short, there are no easy answers to environmental control.

- Second, people are the prime determinants of effective control—who they are, what they do, and most important, how well they do it. We have procedures, equipment, mechanical, and medical weapons to fight the constant battle, but we have not been able to develop a cure for human indifference or carelessness. We have not developed a hospital worker who functions effectively without supervision. No physician, nurse, or administrator can safely assume that control measures are taken without constantly reaffirming the fact through direction, supervision, training, and modification of procedures to fit changing circumstances.

A few examples may illustrate the significance of the hospital as a source of public health problems when environmental controls are lacking or poorly administered.

The most highly publicized type of hospital infection in recent years has been Staphylococcal disease. In postoperative sepsis it has figured significantly for years, with an alarming upsurge in incidence because of the development of drug-resistant strains. It has been particularly evident in infants, both as pyoderma and as Staphylococcal pneumonia. A study of 6 years ago cites one hospital ". . . with 10 percent of total deliveries, produced 20 percent of the cases of infant pyoderma, 45 percent of those of maternal mastitis, 100 percent of those of infant mastitis, and 75 percent of those of neonatal mortality from Staphylococcal disease occurring among 1,456 mothers and their infants delivered in 15 community hospitals . . ."[16] of a major city within 1 month.

High infection rates of neonatal Staphylococcal infection persist in many areas, not often with the high mortality rates cited above, but nonetheless in more than 50 percent of infants after discharge in some localities. Staphylococcal pneumonia is not an uncommon cause of death in patients who are debilitated, aged, or both. It is one of the more common postsurgical complications and is often a secondary factor in severe influenza cases. Increased attention has recently been drawn to Gram-negative organisms as the causative agents in postoperative infections following intracardial surgery,[17] and in epidemic meningitis of the newborn.[18, 19] Outbreaks of *Salmonella derby* infections, totaling nearly 1,200 cases, 75 percent of them hospital isolations from 40 institutions in 25 states and the District of Columbia, illustrate the poten-

tial of the hospital as a focus of infections as well as the chief resource to combat them. In this instance, extensive secondary person-to-person disease transmission followed the primary infections, which resulted from the patients' ingestion of contaminated raw eggs in eggnogs, and in soft-cooked or otherwise undercooked egg dishes. Cracked eggs had been purchased by dietary departments, and proper care was not taken to prevent their use in the raw or undercooked dishes mentioned.[20]

These examples emphasize that patient and community safety in and from the hospital is not a matter of circumstance, but the reward of constant vigilance. The medical and nursing professions, with their highly developed awareness of personal aseptic techniques in surgical and medical care procedures, have only gradually come to realize the importance of clean air, clean surfaces, sanitary handling of wastes and soiled bedding, sanitary food service procedures, and a host of other environmental factors. When properly understood and meticulously followed, environmental control measures provide necessary support to the medical profession's efforts in healing and protecting the sick during both treatment and recovery.

The hospital and its population are dynamic, organic parts of the community in all its aspects. Patients, staff, visitors, auxiliaries, are not "someone else," but are our own friends, relatives, and families. The nature of the medical care institution, of necessity, brings together the infected and the susceptible. Their protection depends on the effective administration of clinical and environmental skills.

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Chapter II

PRINCIPLES OF BACTERIOLOGY

John R. Boring, III

PATIENTS OCCASIONALLY contract a bacterial infection during their hospitalization. Viral and mycotic infections require discussion beyond the scope of this text. Accurate statistics concerning the numbers of such hospital-acquired infections are not readily available, but medical personnel are generally aware such occurrences are sufficiently frequent among certain patient groups to pose a definite problem within the hospital. A clear conception of the characteristics of the microorganisms responsible for hospital infections can provide a basis for establishing measures to limit their occurrence.

Patients most susceptible to infection include those who have received an indwelling catheter, have undergone prostatectomy, have been severely burned, or are on long-term antimicrobial therapy. Newborn infants, especially premature babies, are highly susceptible to certain infections. Also at risk are surgical patients in all categories whose exposure may coincide with some specific environmental hazard. Respiratory infections are a definite hazard, not only as pneumonia in aged or debilitated patients but as secondary infections following surgery and severe influenza cases.

Some factors contributing to the problems are obvious. Modern medical practice has saved the lives of many patients who formerly would have succumbed at an early stage in their disease. These include severely burned patients and those suffering from chronic but life-terminating conditions. Such persons are highly susceptible to infection. Another factor is the prolonged and sophisticated surgery now practiced which carries an attendant risk of infection. However, the factor most widely cited for the increase in hospital infections has been the change of microbial flora in response to the common use of antimicrobial drugs.

The widespread use of antibiotic therapy in hospitals since the late 1940's appears to have resulted in two related problems. One is the increase in drug-potentiated infections. The other is the dynamic influence of antibiotics on microorganisms resulting in the development of drug-resistant bacteria.

Drug-potentiated infections occur in patients on long-term antimicrobial therapy. Often, the causative bacteria are not considered to be disease producers but are resistant to antibiotics.

The mechanism by which drug-resistant bacteria survive within the hospital is not entirely understood, although it is clear that continued antibiotic usage has favored their development. In this connection, evidence suggests that the strains of bacteria causing hospital infections are more common in the hospital than outside it. Thus the term "nosocomial" flora is used to refer to a microbial flora peculiar to the hospital. It is clear that a nosocomial flora of resistant microorganisms may become established through the continued use of antimicrobials.

The bacteria responsible for most hospital-acquired infections may be divided into two general categories: Gram-negative, aerobic non-spore-forming bacteria, and *Staphylococcus aureus*. The Gram-negative bacteria belong to various genera including *Escherichia*, *Pseudomonas*, *Salmonella*, *Achromobacter*, and *Moraxella*. A more detailed description of these bacteria is given later. However, one important point about these microorganisms should be noted—while some bacteria causing hospital infections are known pathogens, many, such as those belonging to *Escherichia* and

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Moraxella, usually have low pathogenic propensities. Thus, there has arisen within many hospitals a situation in which commensal bacteria act as pathogens.

HOSPITAL-ACQUIRED INFECTIONS

The problem of acquired infections will differ from hospital to hospital for a variety of obvious reasons, including hospital size, practices related to antibiotic usage, and the overall quality of employee supervision. For this reason an attempt has been made to consider those general situations which could develop in most hospitals. These infections include:

I. Infections caused by Gram-negative commensal bacteria acting as pathogens
  a. urinary catheter-associated infections
  b. infections following prostatectomy
  c. burn infections
  d. infections in the newborn
II. *Staphylococcus aureus* infections
  a. nursery epidemics
  b. surgical infections
III. Infant diarrhea
IV. Infections caused by *Salmonella* and *Shigella* types
V. Infections caused by the Neisserialike bacteria: *Moraxella* and *Mima*.

Infections of the Urinary Tract. Hospital infections involving the urinary tract are commonly encountered. The urinary catheter has received considerable attention as a source for introducing the bacteria responsible for these infections into the body. In some hospitals, catheter-associated urinary tract infections are the most commonly reported acquired infection.[7] *Escherichia coli* and *Pseudomonas aeruginosa* usually are found as the causes of these infections. The *E. coli* bacteria are normal inhabitants of the intestinal tract of man; most persons harbor the organisms throughout their lives. The extraintestinal presence of *E. coli* is considered an indication of fecal contamination.

Pseudomonas aeruginosa is indigenous to man and may be found in feces, in the ear, and on the skin, especially of the hands. However, its occurrence on or in these sites is apparently low, and many persons do not harbor the organisms as part of their flora.[2] Since both *E. coli* and *Ps. aeruginosa* are indigenous to man, it is not surprising to find these organisms as part of the hospital flora. However, it is not known whether the source of the bacterium causing catheter-associated infections is usually the patient's own flora, or the hospital environment. Obviously, organisms from either source could contaminate a catheter and be introduced into the urinary tract.

Post-Prostatectomy Infections. Urinary tract infections are not uncommon in men following prostatic surgery. *E. coli* is often the infecting organism in these cases. Three antigenic types of *E. coli* are most often responsible for these infections. These types, designated as 0:4, 0:6, and 0:75, also have been found in the feces or urine more often in hospitalized persons than in the general community.[3] This evidence suggests the existence of a nosocomial *E. coli* flora. These three types cause urinary tract infections far out of proportion to their incidence in the stools of men hospitalized for prostatic surgery. A recent study has indicated the source of the *E. coli* causing post-prostatectomy infections.[3] Approximately half of the infections which developed were the result of contamination with bacteria from the hospital environment, while the remainder appeared to have emanated from gut flora.

Burn Infections. The bacterium *Pseudomonas aeruginosa* has become one of the most potent infectious agents as a cause of septicemia and death in the severely burned hospital patient.[4] This organism has assumed importance during an era when primary infection of burns by organisms such as *S. aureus* and the streptococci can be limited with the use of antibiotic therapy. The relatively high resistance of *Ps. aeruginosa* to most antibiotics has exaggerated its pathogenic potential, and invasion of burned tissues by the organism results in infections which are difficult to [illegible].

Lowbury and Fox, in a study to determine the prevalence of *Ps. aeruginosa* in burns in hospitalized patients, found as many as 52 percent of burns infected with this organism.[2] They were able to show that contaminated burns or wounds were the main source of *Ps. aeruginosa* which was then spread to uninfected patients via the air or through direct contact. That direct contact could be responsible for spread was shown by the isolation of *Ps. aeruginosa* from the hands of 38 percent of nurses in burn wards.[2]

It thus appears reasonably certain that burn patients become infected with *Ps. aeruginosa*

whose source is within the hospital environment and that the bacteria reach the burn site either through the air or by direct contact.[5]

Infections in Newborns. Outbreaks of infections, often fatal, have been reported with increasing frequency in the newborn, especially in premature babies. A variety of Gram-negative bacteria have been identified as causative organisms. These include Salmonella types, *Pseudomonas aeruginosa*, *Achromobacter*, *Flavobacterium*, and *Proteus* species. In most cases, contaminated hospital equipment has been identified as the source of bacteria in infections of this nature.

Humidifying apparatus[6, 7] incubators,[8] and faucet aerators[9] all have been incriminated in these outbreaks. The presence of Salmonella and Proteus types on this equipment is indicative of fecal contamination, while the other organisms mentioned are commonly found in water.

Staphylococcus Aureus Infections. Infections of newborns, of patients, and of hospital personnel with *S. aureus* bacteria are widely recognized to be among the most serious infectious disease problems within the hospital.[10] This organism may cause boils, furuncles, extensive body lesions, and fatal septicemias. Many strains of *S. aureus* have become drug resistant since the advent of antimicrobial therapy, and infections caused by these micro-organisms often present a treatment problem. Their primary source is considered to be a person who is continuously carrying the organism within the nose and on the skin. The principal mode of transmission is now believed to be by direct contact.[11] The nasal carrier may or may not be suffering from a disease problem caused by these bacteria, but he must nevertheless be considered a hazard to his contacts. The carrier, if permitted to work in a nursery, may transmit the organism to a number of newborns initiating a staphylococcal epidemic. There is at present no dependable method to eradicate the *S. aureus* organisms from a carrier's nose, so assignment of the carrier to a noncritical area is indicated.

Surgical infections with *S. aureus* are often serious. Carriers of *S. aureus* on the surgical staff are a potential hazard to their patients, especially since the organism may be harbored on the skin and in the nose. Contaminated polyethylene intravenous catheters have been reported as the portal of entry for *S. aureus* in several serious staphylococcal septicemias.

Infant Diarrhea. Some types of the colon bacillus, *E. coli*, are responsible for institutional and hospital outbreaks of infant diarrhea. This disorder spreads rapidly from infant to infant in a nursery, with a varying fatality rate that may rise as high as 40 percent. Bray[12] in 1945 first emphasized the association of a particular E. coli type with outbreaks of infantile diarrhea. At present 11 types of *E. coli* are recognized as a cause.[13] The principal mode of spread of these organisms from baby to baby is direct fecal contamination. This may relate to poor hygiene on the part of the medical staff, failure to wash hands after changing diapers, bathing of infants at a common table, common weighing scales, and contamination during formula preparation. It is not known exactly how these organisms are initially introduced into the nursery. One possible source may be contamination of the baby with its mother's flora at birth. During epidemics, the organisms may be easily spread from infant to infant since the whole of a sick infant's environment may be contaminated, including the air around the incubator.

Enteric Infections. Hospital-acquired enteric infections caused by the food-poisoning Salmonella bacteria, although known to occur, have not been considered common. However, recent evidence indicates that these infections may occur more often than previously suspected.[14] The organism may be introduced into the hospital by a carrier who may or may not have symptoms and may then be spread by fecal contamination from patient to patient. However, in such a case, the spread is usually limited. The Salmonellae also may be introduced by means of a food item. In those instances, large numbers of patients may become infected. In several recent large Salmonella outbreaks in hospitals eggs have often been the source of the organism, and eggnog used for patients on special diets has been the material by which the Salmonellae were spread. In some outbreaks the infection has been limited to those patients eating the contaminated food item. However, in a recent outbreak caused by *Salmonella derby* introduced by contaminated eggs, it could be shown that spread occurred from patient to patient, probably through direct contact. These outbreaks demonstrate several aspects of hospital-associated enteric infections. The causative orga-

nisms usually are not a part of the hospital flora and often are not resistant to antibiotics, but once introduced into the hospital they find fertile ground in susceptible hosts and may spread from patient to patient, involving a large number of the hospital population.

Bacillary dysentery caused by Shigella types is found most often in institutions other than hospitals. In recorded hospital outbreaks, deaths are most frequent among infants and elderly debilitated persons. Spread is apparently by direct contact with unrecognized cases, or indirectly through fecal contamination during nursery procedures, or sometimes through foods. Here again, the organism is apparently not a part of the usual hospital flora and is not favored within the institutional or hospital environment. These infections are of interest and importance because once introduced by a carrier they may spread rapidly from person to person.

Infections Caused by Moraxella—Mima Organisms. Infections caused by the closely related Gram-negative bacteria named *Moraxella lacunata*, *Mima polymorpha*, and *Mima vaginicola* have been reported as frequently responsible for disease in man within the hospital. They have been associated with meningitis, pneumonia, urethritis, and burn infections. Many of the infections caused by these organisms occur in patients with underlying illnesses such as malignancies, slow-healing wounds, and burns. The apparent increase in infections by these bacteria parallels a similar increase in infections caused by other Gram-negative bacteria and by Staphylococci. The suggestion has been made that these organisms may be pathogens of low virulence that can only infect hosts of low resistance. As the population of debilitated persons within the hospital increases, some increase in infections by these bacteria may be expected. Unfortunately, too little is known about the normal habitat of these organisms to accurately define whether they are primarily part of the enteric, respiratory, or skin flora. They have often been isolated from the urinary tract.

CHARACTERISTICS OF SOME BACTERIA CAUSING HOSPITAL-ACQUIRED INFECTIONS

E. coli is a normal inhabitant of the intestines of man and other vertebrates. Its presence outside the intestine indicates fecal contamination. *E. coli* usually lives and multiplies within its host without producing disease. The infections caused by this organism are instances in which an ordinary commensal bacterium acts as a pathogen. *E. coli* is a Gram-negative, rod-shaped bacterium which grows on ordinary laboratory media. It may be isolated from feces or other sources on a special or selective differential medium such as MacConkey's Agar, on which it produces distinctive colonies. The organism is identified by its biochemical and serological reactions. A preliminary identification can be made if the organism ferments lactose, if indol is formed, and if neither acetylmethylcarbinol is formed nor citrate utilized. Confirmation may be made by serological procedures. There are more than 140 distinct types of this organism having characteristic somatic antigens. Unknown organisms suspected as *E. coli* are identified with antisera prepared against known antigenic types.

Pseudomonas aeruginosa, the cause of secondary infections in burns and wounds, is Gram-negative and rod shaped. It is indigenous to man and may be isolated from feces or from the skin, especially that of the hands. However, only about 3 percent of stools from healthy individuals will yield *Ps. aeruginosa*.[2] The organism grows well on ordinary laboratory media, on which some strains will produce a definitive pigment and odor.

Pigmented as well as nonpigmented types are identified mainly on the basis of a variety of biochemical reactions. Pseudomonas species are aerobic, and this property is useful in identifying the organism. Staining of flagella may be used as another identifying test. More rapid and definitive identification of *Ps. aeruginosa* types is now being attempted in several laboratories by using phage typing.

Salmonella types are found in the intestines of warm-blooded animals and occasionally in reptiles. Poultry serves as the reservoir for these organisms in nature, and man may also carry Salmonellae without showing symptoms. Fecal contamination of foods is the usual mode of spread of Salmonellae. Salmonellae types may be isolated from feces, from foods, and from contaminated environmental sources. Since the organism may be present in low numbers in these materials, cultures usually are enriched by growing in liquid media, such as tetrathionate broth, in which their growth is favored over other bacteria which may

be present. The Salmonellae are isolated on differential and selective media such as brilliant green agar, on which they produce distinctive colonies. Salmonellae are identified on the basis of their biochemical and serological reactions. A variety of biochemical tests must be performed to identify a suspicious organism as one of the Salmonellae, but serological methods offer a rapid and definitive method for identification. There are over 700 specific antigenic types of Salmonellae, and antisera prepared against known types are used to identify unknown types.

Shigella usually are found only in the feces of the sick, but may be found occasionally in the feces of asymptomatic convalescents or asymptomatic carriers. The bacteria usually are spread person-to-person by direct fecal contamination. The Shigellae are isolated from feces on selective and differential media such as MacConkey's or Salmonella Shigella Agar, where the organisms produce characteristic colonies. The Shigellae are identified by their characteristic biochemical and serological reactions. A variety of biochemical tests are necessary for identification. A number of antigenic types of Shigella are known and isolates may be identified by their reaction with specific antisera. The most common types in the United States are *Shigella flexneri* and *Shigella sonnei*.

The Neisseria-like bacteria, *Moraxella* and *Mima*, present a classification problem because of the variety of organisms described as belonging to these provisional groups. The organisms do, however, have certain similar characteristics. The bacteria are Gram-negative but have a tendency to retain some of the crystal violet stain so that the rods appear lavendar. The organisms are pleomorphic, encapsulated, nonmotile, nonpigmented, aerobic, and do not reduce nitrates to nitrites. They will develop on the usual laboratory media.

The organisms may be recovered from conjunctiva, the nasal mucosa and the genitourinary tract of persons without disease. These bacteria appear to have low disease-producing capacities which can nevertheless cause problems in debilitated persons.

Staphylococcus aureus is a Gram-positive, spherical-shaped organism which grows well on ordinary laboratory media such as Trypticase Soy Agar. It may be isolated from a swab of the nose or the skin of a carrier. Some individuals constantly carry the organism in the nose, others intermittently, and some individuals never carry it. Most *S. aureus* produce a distinctive golden yellow pigment on agar, and colonies also have a distinctive morphology. Most disease-producing types of *S. aureus* are considered to elaborate the enzyme coagulase, which causes clotting of plasma. This definitive characteristic is used in identification. Different *S. aureus* types are identified by bacteriophage typing. There are a great variety of phage types, but only a few are usually associated with Staphylococcal disease at a given time. Currently, the most common of these is the type 52/52A/80/81.

SUMMARY

The solution of the problem of hospital-acquired bacterial infections is not yet at hand. However, certain precautionary measures may be applied toward limiting the problem.

All mechanical devices introduced into a patient as adjuncts to surgical or other procedures must be considered as sources of contaminating microorganisms. Thus, urinary and intravenous catheters always should be considered as potential sources for introducing microorganisms. Apparatus used for premature infants such as incubators, humidifying machinery, and faucet aerators must also be suspect. Umbilical clamps may be another source for infection of babies. These always should be sterilized and handled in such a manner as to avoid contamination.

Carriers of Staphylococci are potential hazards to their contacts. This is especially true of those who work with the newborn. These carriers should be removed from contact with susceptible babies and given other duties. Nurseries involved in Staphylococcal epidemics should be cleared as soon as possible. The newborn should not be introduced into these nurseries and should be protected from any contact with infected babies. The same holds true of nurseries experiencing epidemics of infant diarrhea. In the latter situation, special hygienic precautions should be practiced and especial care taken not to transmit organisms from baby to baby. As always in nursery procedures, meticulous care in handwashing—and gloving when indicated—is the cornerstone of good control.

In the situation of hospital-acquired enteric infections such as those caused by Salmonellae and

Shigellae, patients should be immediately quarantined and special precautionary measures practiced to assure that the infection is not spread from the initial cases to secondary cases, either by direct contact, by indirect fecal contamination, or by aerosol spread. All food for patients should be adequately cooked and carefully handled. The use of raw or undercooked eggs in the hospital should be especialy discouraged.

In the special case of burned patients, certain precautionary measures will reduce the likelihood of infection. Specially constructed isolators are now available in which the patient may be kept in a limited environment, separated from the hospital environment. Where this isolator has been used, the frequency of contamination of severely burned patients has decreased. It also may be used for other high-risk patients.

Necessary precautionary measures, usually known to a well-trained staff, will control or at least limit the acquisition and spread of infection if good supervision insures that they are properly carried out. It should be emphasized that these measures should always be practiced. Surveillance within the hospital is also of extreme importance. Such surveillance includes periodic examination of the hospital staff to detect Staphylococcal carriers, especially student nurses who are a high risk group. Frequent periodic examination of hospital equipment to insure that sterilization has been accomplished also should be a routine control measure.

Finally, it must be emphasized that all medical and auxiliary personnel require education and frequent reminders concerning the potential dangers of hospital infections. This education should include an understanding of the causes leading to hospital-acquired infections, and of the bacteria contributing to them. Education, in concert with alert supervision, will result in better precautionary measures to reduce the incidence of hospital-acquired infections.

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Chapter III

PRINCIPLES OF EPIDEMIOLOGY

Philip S. Brachman

HOSPITAL-ASSOCIATED infections remain a potential threat to all people having contact with hospitals, whether they are patients, personnel, medical staff, or vistors. Many factors influence the risk involved; some are host-related, and others are associated with the environment or the etiological agent. The true incidence of hospital-associated infections is unknown. There are several institutions in which moderately effective surveillance programs have been conducted,[1-5] but these programs and the data developed are not representative of all hospitals and of all infections.

The problem involves all potentially pathogenic microorganisms—bacterial, viral, rickettsial, fungal, or protozoal. During the past years, most attention has been given to Staphylococcal infections, with only little attention being directed toward others. Reports in the literature indicate that Staphylococcal infections account for approximately one-half of hospital-associated infections, with the other etiological agents, mainly the Gram-negative organisms, being responsible for the remainder. More information is needed concerning the total problem of hospital-associated infections.

Some published reports indicate no demonstrable increase in the incidence of hospital-acquired infections over the past years, at least when analyzing one or several standard surgical procedures.[6, 7] Other reports suggest that hospital-associated infections have become a more serious problem during recent years.[8] Several factors and events related to patients suggest that the risk of developing infections while in the hospital has increased during past years.[9] These include age, concurrent diseases, and diagnostic and therapeutic procedures. Basically, hospitalization allows a greater opportunity for contact between the patient and infectious agents than is found in the home or community.

The average age of patients currently being admitted to hospitals is gradually increasing. Older age is associated with decreased resistance to infection. The primary disease process itself for which the patient is admitted will frequently be associated with reduced resistance to infections. Thus, the patient with a low hemoglobin content or white blood cell count, aberrant serum proteins, shock, etc., is more susceptible when brought into contact with infectious agents. Additionally, patients are admitted to hospitals with concurrent chronic diseases not necessarily primarily responsible for admission, but which are associated with decreased resistance to infection. Among these are diabetes mellitus, hematological diseases, cancer, chronic nephritis, and cirrhosis.

Another reason for the increased risk of developing hospital-associated infections is the variety of diagnostic procedures to which patients are subjected. Such procedures as venapuncture, biopsies, aspirations, and cardiac catheterization provide an increased opportunity for developing infections. Also associated are the use of broad-spectrum antibiotics, steroids, full-body irradiation, blood transfusions, intravenous therapy, catheterization of the bladder, splenectomies, surgery—especially prolonged cardiac surgery, and the challenge of a foreign body (sutures).

In addition to these patient factors, the hospital environment itself suggests an increased opportunity for development of infections. The admission of patients with undiagnosed infectious diseases to hospitals allows the spread of microorganisms to other patients before the diagnosis is

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made and appropriate control measures are instituted. Studies have shown that microorganisms isolated from within the hospital, either from hospital personnel or from the environment, have an increased resistance to antibiotics compared to microorganisms isolated from outside the hospital. Our current knowledge of some infections, such as those caused by the Staphylococci, indicates that the organisms with increased antibiotic resistance are more frequently associated with disease.[10] Another factor allowing for the ease of transmission of disease within hospitals is the intimate contact between patients and staff, allowing for direct transmission of microorganisms. Thus, there is a greater risk of highly susceptible patients developing hospital-acquired infections.

A few terms need to be defined. The term "infection" refers to the multiplication of an infectious agent in the body tissues. "Carrier state" refers to the presence of an infectious agent in or on the body, in the absence of signs or symptoms of recognizable clinical disease. "Disease" or "sepsis" is the presence of symptoms resulting from the action of an infectious agent. "Colonization" refers to the presence of an infectious agent, whether the subject shows symptoms, or is asymptomatic to that agent.

"Hospital-associated infections" are those acquired in hospitals, as well as those present upon admission, having been acquired prior to hospitalization. "Hospital-acquired infections" are those acquired only in the hospital, whether the clinical expression of disease occurs during hospitalization or after discharge. Infections present upon admission are those clinically apparent, or incubating, at the time of admission. Thus, a patient who is in the incubation period of an infectious disease upon admission and subsequently develops the clinical signs of infection has not developed a hospital-acquired infection. Nevertheless, an infection not clinically evident upon admission is important, and may be related to the spread of infection within hospitals. An example would be a child with a broken leg, who is found to have clinical rubella within several days after admission.

Also of importance are patients who acquire infections while hospitalized, but do not develop the clinical signs until after discharge. Some studies of nursery outbreaks of Staphylococcal disease disclosed that over 50 percent of the infants developed clinical evidence of the disease after discharge.[11] Newly delivered mothers who develop breast abscesses usually show clinical signs only after discharge from the hospital. Other studies have shown that approximately 25 percent of postoperative patients who develop wound infections do so after discharge from the hospital.[12] For purposes of full surveillance and control, all infections that develop after discharge which are hospital-related should be enumerated.

All hospital staff members are potential links in the chain of hospital infections. Not only may staff members be carriers of infectious agents that may spread to susceptible patients, but they may acquire infections from patients, which, if not diagnosed, can lead to spread of disease. Additionally, these employees or staff members may carry infectious agents into their homes and communities with resulting development of disease. Visitors to the hospital also can either be carriers or have active disease, bringing organisms into the hospital or transmitting infectious agents into their homes and communities.

ROUTES OF TRANSMISSION

Infectious agents are disseminated from lesions, secretions, carriage sites, and the environment, including fomites; they are spread by either direct or indirect routes depending upon the agent. Generally, person-to-person transmission, an example of direct spread, is the route of greatest importance in hospital-acquired infections. Individuals in such a chain may either be asympto-

danger to other individuals at that particular time. For reasons not well understood, she may at some other time become a disseminator and be a source of Staphylococci for susceptible persons.

Most hospital-acquired infections probably are transmitted by the direct route. The specific method of spread is frequently by personal contact between the carrier and the recipient, with transmission via contaminated hands. The importance of this route has been demonstrated by some recently reported experimental work.[13] In these experiments, an unmasked nurse carrying phage typable coagulase-positive Staphylococci in her anterior nares, read aloud in a nursery without touching the newborn infants; the strain she was carrying was not transmitted to the infants. However, when she handled successive infants without washing her hands, there was transmission of her Staphylococcal strain to the infants. In another experiment, the same authors have shown the spread of Staphylococci from colonized newborn infants to uncolonized newborn infants by nurses' unwashed hands. Spread was prevented by hand washing between handling of each infant.

The airborne route has been incriminated in some reports of direct transmissions, but has not been shown to be as important as person-to-person spread. However, the work by Riley and associates clearly indicates that tuberculosis can be spread by the airborne route.[14] A report of coccidioidomycosis in the Southwestern United States described transmission from a patient with bilateral osteomyelitis to six members of the hospital staff who developed respiratory disease; spread of the agent probably occurred via the airborne route.[15] Walters has reported two cases of postoperative wound infection that appear to be the result of airborne spread from a disseminating person in the operating room.[16] The airborne route may be important in the transmission of various childhood diseases such as chicken pox, rubeola, and rubella among patients on the pediatric wards.

Among reports discounting the airborne route of spread is the work by Rammelkamp already mentioned.[13] In another report, evidence is given underplaying the importance of this route in the development of postoperative wound infections.[17] In this report, an evaluation of total room ultraviolet irradiation in operating theaters has shown that even though total counts of airborne bacteria may be reduced up to 63 percent, the overall incidence of postoperative wound infections was not changed. Thus, at least in this study which involved 14,854 operations, the airborne route of infection was not considered important.

The patient himself may be a carrier of the organism with which he subsequently becomes infected. This has been noted in postoperative staphylococcal wound infections where the anterior nares are the site of carriage.[17A] Urinary tract infections following catheterization may be the result of infection with organisms already in the urethra or in the perineal area of the patient.

The indirect spread of microorganisms refers to transmission via fomites, food, liquids, or other inanimate objects. There are published reports concerning the transmission of infectious agents via bedpans, rectal thermometers, linen, water pitchers, dust, and disinfectants.[25-29, 43] At the same time, there are other reports that do not support fomites as important in the spread of hospital-acquired infections.[31] Even though an inanimate object may be contaminated with a virulent organism, it may not be a source of infection. Perry et al. have shown that group A Streptococci found on blankets as a result of their use by recruits with streptococcal pharyngitis, though transmissable to new recruits, did not cause clinical disease among them.[24] It is important to temper judgment concerning microorganisms found on fomites with evidence concerning their pathogenicity and transmission. Outbreaks of food poisoning due to Salmonellae, Shigellae, Staphylococci, or Clostridia have been reported in which the organism has been spread from food, either directly to patients or through food handlers to patients. The widespread hospital-associated outbreak of *Salmonella derby* gastroenteritis in 1963 and 1964 is an example of initial spread of Salmonella organisms from contaminated food to patients, and subsequently from patients to employees.[18]

Retention urinary catheters form a pathway for the transmission of organisms through the urethra into the bladder, often resulting in development of urinary tract infections. If the catheter is left in place for over 72 hours without special care (such as constant closed drainage with an antiseptic solution), there is almost 100-percent chance of an infection developing. It has been reported that transmission of *S. typhi-murium* via dust from a vacuum cleaner in a pediatric ward ac-

counted for 21 infections over an 11-month period.[20] The development of serum hepatitis following the use of contaminated blood is another example of spread via inanimate objects. The contamination of humidifying equipment in nurseries, with a variety of Gram-negative organisms, has resulted in infections among newborn infants.[21-23]

SURVEILLANCE

As previously mentioned, most available information concerning the surveillance of hospital-associated infections is related to Staphylococcal disease. The overall reported incidence of Staphylococcal infections varies from 0.5 percent to approximately 5 percent for all patients admitted to hospitals. Most studies indicate that approximately one-half of hospital-acquired Staphylococcal infections occur among surgical patients; one-quarter among medical patients; and the remainder among pediatric, obstetrical-gynecological, and miscellaneous patients.[2-5]

Post operative wound infection rates vary from 1 to 20 percent, with a mean of somewhere between 5 and 10 percent. The variation will depend upon methods of surveillance, the definition of infection, types of surgery, patient population, time of surgery, and other definable and undefinable factors. Various reports deal with some of these factors, such as type of surgery, season of the year, age of the patient, and preoperative days in the hospital.[4, 10, 17]

Surveillance programs investigating all hospital infections indicate that from 20 to 50 percent of hospital-acquired infections are caused by Gram-negative organisms. Studies stressing the increasing importance of these infections among hospitalized patients have been reported by Finland and by Altemeier.[8, 55] A recent study at the Boston City Hospital reported a prevalence of hospital-acquired infections of 13.5 percent, with 22 percent of these resulting from infections with Gram-negative organisms.[47]

To emphasize the broad scope of the problem encompasses all types of infections, a brief summary follows of some of the hospital-acquired infections reported in the literature.

Much has been written concerning Staphylococcal infections, including some comprehensive reviews.[4, 10] A significant problem is the asymptomatic carrier who is disseminating Staphylococci. Epidemics related to a nurse carrier have been reported among newborn infants; postoperative infections have been related to a physician carrier.[54] As mentioned, the patient may serve as the disseminating carrier for his own clinical infection. Furthermore even though most Staphylococcal infections are due to coagulase-positive organisms, coagulase-negative Staphylococci can also cause serious disease, such as bacterial endocarditis following cardiac catheterization or cardiac surgery.

Streptococcal infections have historical significance as a major cause of puerperal sepsis in maternity wards in the mid-1800's. With the advent of improved antisepsis, this disease has decreased significantly, but occasionally cases of puerperal sepsis still occur. Dineen has reported that beta hemolytic Streptococci account for 3 percent of the postoperative wound infections in one large city hospital.[35] Additionally, this organism can be associated with infections of subcutaneous tissues resulting in gangrene. Upper respiratory tract Streptococcal infections, especially among children, remain a potential problem in hospitals. The occurrence of Streptococcal endocarditis among patients who have previously had rheumatic heart disease may be associated with hospitalization and manipulative procedures, such as oral surgery.

Pneumococcal infections have decreased in prevalence, but remain a potential threat among hospitalized patients, especially the elderly or those critically ill. Transmission of tuberculosis within hospitals is no longer considered a major prob-

218-595 O—67——4

ment or the patient himself, since clostridial organisms are commonly found in the biliary system. Tetanus due to *Clostridium tetani*, though markedly reduced in past years, remains a potential threat, especially among newborn infants whose umbilical stump becomes contaminated. *Clostridium perfringens* food poisoning is a potential hazard associated with the use of food contaminated prior to entering the hospital or contaminated by a carrier during preparation.

Salmonella infections among hospitalized people are being reported with increasing frequency.[18, 19, 41, 50] This organism may be spread through the hospital by means of food, a carrier (personnel or patient), or a symptomatic patient or employee. The food may become contaminated at source of origin or during its processing prior to entering the hospital; or it may become contaminated during further processing in the food service or nursing areas. Cases may occur among any individuals who come in contact with the food.

The other method by which salmonellae are introduced into the hospital is through hospital personnel or entering patients who are excreting salmonellae and contaminate their hospital contacts either directly or indirectly through food.

Shigellosis can be a problem, as indicated by the common source outbreak reported in 1962 when 124 hospital employees and 1 patient developed this disease, probably from consumption of contaminated food.[36, 57] Person-to-person transmission is also a method of spread in institutions, and is often seen in such places as overcrowded mental hospitals.

Enteropathogenic *Escherichia coli*, a frequent cause of diarrhea among infants, spreads rapidly throughout a pediatric ward.[56] A patient may be colonized within the hospital and develop clinical symptoms following discharge. This may result in spread to community contacts. Clinical cases are usually not seen in those above 5 years of age. In addition to causing gastroenteritis, these organisms are the most common bacteria associated with urinary tract infections resulting from catheterization or instrumentation of the urinary tract.

Many reports cite the involvement of contaminated nursery humidifying equipment, oxygen apparatus, water filters, and traps in infections among premature and full-term infants. The organisms involved are of the genera *Proteus*, *Pseudomonas*, *Alcaligenes*, *Achromobacter*, and *Flavobacterium*.[21-23, 50, 52, 53] These outbreaks frequently are associated with high mortality rates due to the young age of the patient and the antibiotic resistance of these organisms. *Serratia marcescens* and *Moraxella* (Herella) also have been reported as causing infections among hospitalized patients.[46, 47] Listeria meningitis has been reported following prostatectomy.[45] Children with the common bacterial diseases usually are not admitted to hospitals, but these infections still remain a potential hazard within hospitals, especially if a patient is admitted in the incubation periods of whooping cough, diphtheria, or scarlet fever. Hospital-acquired meningococcal meningitis is also a potential problem among patients and staff members.

Fungi have been reported as the cause of hospital-acquired infections.[51] Thrush in newborn infants is related to maternal infection with monilia. Aspergillosis has been reported as a complication of newborn infant exchange transfusions.[42] In an outbreak of coccidioidomycosis among six members of a hospital staff, the source of infection was a 10-year-old child with bilateral coccidioidomycosis osteomyelitis of both tibias.[15] One case of hospital-acquired cryptococcosis has been reported in a 62-year-old female with chronic lymphatic leukemia. She was infected following contact with another patient with skin lesions and respiratory symptoms caused by cryptococcosis.[48]

Some parasitic diseases may result from hospital contact with other patients infected with the etiologic agent. *Entamoeba histolytica* may be spread directly through the fecal-to-oral route, or by means of contaminated food or water.[57] The ease with which pinworm infections spread among school children suggests that this could be a problem among hospitalized children.[59]

Viral diseases may also be acquired during hospitalization.[61] Among the acute respiratory viral infections, one that has always been of great concern is influenza. During influenza epidemics, the spread of this agent among hospitalized patients as well as the hospital staff must always be considered. Para-influenza-3, a myxovirus, and respiratory syncytial (R.S.) virus have been shown to spread among hospitalized infants.[58]

Among the enteric viruses, hepatitis is one of the more significant hospital-associated infections to be considered.[66] A serious problem concerning virus A, the infectious hepatitis virus, is the unrecognized or subclinical infection. This situation allows for the spread of the virus to other

patients or to hospital staff members who come in contact with fecal material from the infected patient. Infectious hepatitis is frequently a persistent problem among patients in mental institutions or chronic disease hospitals.[57] There are also reports of infectious hepatitis being transmitted by food contaminated by food handlers.[63]

Virus B, the serum hepatitis virus, is usually spread as a result of the use of contaminated equipment or the infusion of contaminated blood or blood products (fibrinogen). A recent study has clearly indicated the increasing risk of the patient's developing hepatitis as he receives an increasing number of units of blood during a single hospitalization.[38] The risk following the receipt of one unit of blood was 1.4 percent; two units, 2.7 percent; five units, 6.7 percent; and six units, 8.3 percent. There have also been reports of the potential hazard of transmitting hepatitis among hospitalized patients by means of contaminated dental or barber tools.

Poliomyelitis can also be transmitted among hospitalized patients.[62, 63] Coxsackie viruses have been associated with hospital infections; in fact, the first cases of Coxsackie B virus were diagnosed among newborn infants who developed acute myocarditis from Coxsackie B–3 in a maternity institution in South Africa. Cases of Coxsackie B–5, ECHO–18, and ECHO–19 disease have been reported among hospitalized patients and personnel.[32–34, 64]

Smallpox must always be considered a potentially serious problem among unvaccinated or inadequately vaccinated hospital patients and staff members.[61] The recent outbreaks in Great Britain, Sweden, and Germany (1962–63) resulted in 123 cases, 58 percent of which were hospital acquired. Rubeolla, rubella, and chicken pox have all been reported to have spread among patients on pediatric wards. Herpes simplex infections have been reported among premature infants, as well as among nurses having contact with oral secretions from patients infected with the herpes virus. Herpes zoster infections have also been involved in an outbreak of hospital-acquired disease.[65]

This discussion is merely a partial review of the variety of hospital-acquired infections described in the literature. Other microorganisms have undoubtedly been involved, but without surveillance their occurrence has passed unrecognized and unrecorded.

METHODS OF SURVEILLANCE

An effective surveillance program is dependent upon the enumeration of data pertaining to all patients with hospital-associated infections, either during epidemic or endemic situations. One interested person must be charged with the responsibility for overseeing the surveillance program with authority to insure smooth, routine operation. The program must cover the patient during hospitalization and after discharge and must be concerned with the total professional and nonprofessional hospital family, as well as visitors.

A variety of surveillance methods may be used. No one method is all-inclusive; to improve the accuracy of a program, a combination of several methods is recommended. The exact surveillance techniques of any hospital program will depend not only upon the final data desired but also upon the facilities, personnel, and finances available, as well as interest in the program on the part of the administrative and professional staffs.

Overall guidance for the surveillance program must come from the hospital infections committee which should be broadly based in its composition, with every major department, both professional and nonprofessional, represented. Not only should the medical, surgical, pediatric, obstetrical, and laboratory services be represented, but the administrative office, nursing service, housekeeping and engineering departments, and nonprofessional personnel as well. The program supervisor, who may be variously designated as the infection control officer, nurse epidemiologist, or hospital epidemiologist, while not necessarily a member of this committee, should be under its jurisdiction

weekly, or monthly basis. The daily report is of greatest benefit during an outbreak of hospital infections. In these situations, control is dependent upon immediate knowledge of where infections have occurred and the establishment of appropriate control procedures. A weekly summary of patients with infections, successfully used in various hospitals, is more practical for routine surveillance. A monthly report usually does not allow the hospital epidemiologist to see the patient, and many infections may be forgotten in the interval between reports.

The individual patient report is a form filled out, preferably for each patient, whether or not he develops an infection. In some programs, this form is only filled out for patients with infections. There is less chance of missing an infection if the form is used for each patient discharged, even if no infection was noted. Thus, denominator data can be obtained, and each patient is considered individually, whether or not he developed a hospital infection. For patients who develop infections, the reporting form should be filled out and submitted at the time the infection is first observed, so that the surveillance officer can keep the patient under observation. For all other patients, the form should be filled out upon discharge.

The amount of information requested on any of these forms depends upon the depth of the surveillance program. This will be dictated by the interest of the hospital infections committee and personnel directly involved in the program. The simplest type of surveillance form need ask only the patient's name and one question, "Did the patient develop an infection in the hospital?" Accurate, effective surveillance, however, will be difficult if this is the only information available. Basic data requested should include name, age, location in hospital, date admitted, date of onset of infection, type of infection, and culture results. An example of an individual patient reporting form is given in figure 1. The form, of a distinguishing color, should be inserted in the patient's record upon admission. Depending upon when they are filled out, forms may be removed on the nursing unit or in the record room and then sent to the surveillance officer.

The reporting official designated to fill out the infections report forms will vary from hospital to hospital. A professional person, who has the clincial responsibility for that particular patient, is preferable. He may be the private physician, resident, or intern.

In some instances a nurse may complete the forms under the direction of a physician. It should not be the nurse's responsibility to decide if the patient has developed an infection, although she can act as the agent of the physician in completing the forms.

Another method of surveillance is a periodic review of the bacteriological records, noting the isolation of organisms by species, geographic location in the hospital, source of cultures, and similar data. The obvious difficulty in using this method is that the mere recovery of an organism does not indicate whether the patient has clinical disease or is a carrier of that organism. It is possible to send out forms requesting additional information for selected types of organisms identified in the laboratory. The success of this system is dependent upon all infections being cultured. Additionally, if a culture is negative because of improper techniques of obtaining it, or because of delay in receipt of the specimen in the laboratory, an infection may be missed.

Surveillance also can be conducted by a routine visit to the nursing unit by the surveillance officer or his agent, such as a nurse. Each patient can be checked, charts reviewed, or the house and nursing staff questioned regarding presence of infection. Temperature records can be examined, and the use of antibiotics noted as further indices of which patients have infections. In some institutions, surgical wards maintain wound record books which can be reviewed for notations of infections. Another area for surveillance is autopsy reports. These can be examined for evidence of infection found at postmortem examinations.

The surveillance umbrella should be extended to the outpatient department, since, as previously noted, a variety of infections related to hospitalization may not become clinically evident until after discharge. If the patients do not return to the outpatient department, attempts should be made to follow them by other means. The most effective method is a telephone survey, whereby all or selected patients or families are contacted 2 to 4 weeks after discharge and questioned judiciously concerning the development of any infections following discharge.[67] Permission for this type of program must be obtained from the private physicians and hospital administration. Other methods such as contacting the physicians

Name______________________________________

Age____________________ Sex__________________

Date of admission____________________________

Ward____________________ Service_______________

(Addressograph plate should include this information)

1. Was there any evidence of infection at time of admission? Yes ( ) No ( )
2. Did infection develop after admission? Yes ( ) No ( )

Date infection developed______________________

A. Type of Infection:

☐ Respiratory ☐ Postoperative wound ☐ Urinary ☐ Skin

☐ Gastrointestinal ☐ Blood ☐ Eye

☐ Other____

B. Was the infection cultured? ☐ Yes ☐ No

C. Results of culture____

(Predominant organism(s))

Reported by________________________________

Date ______________________________________

Followup: (if followup surveillance is to be conducted)

3. Date of followup__________________________
4. Did infection develop after discharge? ___________Yes ___________No

(If infection developed after discharge, answer above questions)

not only for the obvious benefit to themselves, but as a necessary part of an inclusive surveillance program. If any employee develops an infection with potential dissemination to highly susceptible patients, he should be placed in a noncritical position if he is still able to work. If he is unable to work because of his disease, or if it is felt he should not be working at all because of his infection, it is preferred that he be maintained on the payroll. If personnel are threatened financially when they develop infections, they will not report the development of infectious disease unless its concealment is impossible.

The data developed from the surveillance program should be routinely and regularly analyzed, reported to the hospital infections committee, and summarized in a weekly or monthly report distributed to the professional staff. These data will be the basis for investigations, training programs, setting of standards, and research programs, all of which will lead to improvements in control and prevention of hospital-acquired infections.

Surveillance of hospital infections can be as simple or detailed as the situation demands. A separate person may conduct the program as a full-time job, or a member of the hospital staff may incorporate the surveillance program as part of his activities.

Any hospital can conduct an effective surveillance program.

INVESTIGATION

From the above discussion, it should be reemphasized that in dealing with hospital-associated infections there is need to consider epidemic as well as endemic disease. The surveillance program within the hospital should be geared to determine the endemic level of all infections and at the same time be responsive to epidemic situations.

There is probably a certain low level of hospital-acquired disease among patients that will always occur, regardless of procedures in vogue at the time. However, it is the rise, either sudden or gradual, in incidence of hospital-acquired infections that must serve as the alarm system to the hospital epidemiologist. Any cluster of cases, either in time or geographic area, or any unusual sporadic cases must be investigated. A sudden rise in incidence may represent a common source outbreak, such as an outbreak of salmonellosis related to contaminated food. A slow but steady rise in numbers of cases may represent a person-to-person-spread outbreak, such as seen in the transmission of Shigella organisms from patient-to-patient, or patient-to-staff-member-to-patient. Sporadic cases of importance can be represented by the occasional case of gas gangrene which may follow the use of contaminated surgical instruments due to intermittent malfunction of a steam sterilizer.

When an increase in incidence or an unusual single case occurs, appropriate investigations must be immediately instituted. Once the diagnoses have been confirmed, including obtaining necessary cultures, and the total number of cases determined, then a common source, carrier, break in technique, vehicle of infection, or some other abnormal situation must be considered. Part of the investigative program may be obtaining cultures from potential carriers; from fomites, such as the humidifying equipment in use in the newborn nursery; from surfaces in the operating room; from food or other possible sources of infection: Following these investigations, the data must be analyzed and the most likely source identified. Appropriate control measures should then be instituted.

It is important that control measures be based upon factual evidence available and not upon emotional feelings which lead to "shotgun" attempts at control yielding only sporadic effectiveness. The regular surveillance program can be utilized for evaluation of the effectiveness of control procedures.

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INFECTION CONTROL

Margaret Benson

An infectious disease occurs as the result of a sequence of interdependent or interrelated factors listed below:

1. An infectious agent (microorganism or its toxic products) capable of producing an infectious disease
2. A reservoir of infection (source of the infectious agent)
3. A portal of exist (means by which the infectious agent can leave the reservoir of infection)
4. A mode of transmission (a method by which the infectious agent is transferred from its reservoir of infection to a host)
5. A portal of entry (means by which the etiological microorganism can enter the body of a host)
6. A susceptible host (a susceptible human or animal in which the infectious agent can cause a disease)

If this sequence is interrupted, an infectious disease will not develop. Thus, control programs are directed at interrupting the sequence. Knowledge of the events in the disease process will aid in determining the type of precautions desirable in the care of a patient who has a diagnosed infectious disease, or who has a significant susceptibility to various types of infection.

CONTROL OF INFECTIOUS DISEASES

Control of infectious diseases is directly related to the knowledge of the behavoir of each disease in man, as well as the measures developed to curtail or interrupt the natural sequence of infection.

Some diseases present complex natural histories in which there may be unknown components requiring additional knowledge to formulate effective control measures. Existing information about the natural sequence of typical infectious disease processes and control methods now in use are diagramed in chart 1.

The following examples of control show interruption of one or more occurrences in the natural sequence of the infectious disease process:

1. Control of the reservoir of infection
   (a) Surveillance program of typhoid fever carriers, preventing such carriers from being employed in food handling jobs.
   (b) Use of medical aseptic precautions in the care of patients with communicable diseases such as mumps or typhoid fever
2. Control of a potential secondary reservoir of infection
   (a) Good housekeeping practices to control dust-borne pathogens
   (b) Providing each patient with his own clean blanket and laundering it when patient is discharged
3. Destruction of the reservoir of infection
   (a) Rat reduction control programs for plague and rat bite fever
   (b) Testing programs for bovine tuberculosis or brucellosis in cattle, swine, or goats, with slaughter of infected animals
4. Destruction of the infectious agent when man is a reservoir of infection
   (a) Treatment of typhoid fever carriers
   (b) Treatment of individuals with infectious diseases such as malaria, meningococcal meningitis, and syphilis
5. Reduction of contamination by environmental air conditioning
   (a) Hospital with filtered air-conditioning in critical areas such as the operating suite, delivery room, nurseries, and intensive care units

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218-596 O—67——5

Chart I. Natural Sequence of the Infectious Disease Process

General Reservoir of Infection	*Portal(s) of Exit*	*Vehicle(s) of Transmission*	*Portal(s) of Entry*	
Infectious Agent				Susceptible Host
EXAMPLE A: Typhoid Fever *Reservoir of Infection* Patient ill with the disease, or a carrier				
Infectious Agent: *Salmonella typhi*, Typhoid bacillus	*Portal of Exit* Gastrointestinal tract: feces Urinary tract: urine	*Vehicles of Transmission* Direct or indirect contact with the ill patient or carrier Food such as milk, milk products, poultry, and shellfish, as well as raw fruits, vegetables, and water	*Portal of Entry* Oral-gastro-intestinal tract (ingestion)	Susceptible Host
EXAMPLE B: Pertussis *Reservoir of Infection* Patient ill with the disease, or a carrier				
Infectious Agent: *Pertussis* bacillus	*Portal of Exit* Respiratory tract inclusive of secretions and discharges from laryngeal and bronchial mucous membranes	*Vehicles of Transmission* Direct contact with infected person Droplet nuclei Indirect contact with articles freshly soiled with discharges from the respiratory tract	*Portal of Entry* Respiratory tract	Susceptible Host

(b) Providing for filtered air exhaust from the room of a patient with tuberculosis

6. Control of one possible fomite among many in a hospital
   (a) Proper sanitizing of dishes
7. Control of a reservoir of infection by destruction of vectors
   (a) Eradication of Anopheles mosquito for control of malaria
   (b) Eradication of intermediary snail host of infectious agents causing schistosomiasis
8. Control of a potential reservoir of infection by modifying the vehicle of transmission
   (a) Pasteurization of market milk for prevention of diseases such as bovine tuberculosis and brucellosis
   (b) Water purification to prevent spread of diseases such as typhoid fever
9. Decreasing the host's susceptibility by increasing host resistance
   (a) Use of active immunization against diseases such as tetanus, diphtheria, poliomyelitis, typhoid fever, and smallpox
   (b) Use of passive immunization for previously unexposed pregnant mothers if exposed to German measles, or for an accident victim who has had no tetanus immunization
   (c) Administration of prophylactic medication to a staff member exposed to a patient with meningococcal meningitis
10. Deliberate exposure to increase resistance of the host
   (a) Exposure of a susceptible female adolescent or young female adult to German measles before age of childbearing decreases possible congenital defects in an infant if the mother contracts German measles during pregnancy.

INFECTIOUS DISEASES AND MODES OF TRANSMISSION

Tables I–VI list some infectious diseases, with the significant modes of transmission and portals of entry and exit of the infectious agent. In addition, aseptic practices which may be indicated for a specific disease are noted. The type of medical aseptic technique to be used in the care of a patient should be determined by the physician.

Additional information for this determination may be secured from various references.

In some hospitals, members of the infections committee have developed recommendations for the isolation technique to be practiced in controlling various infectious diseases. Since opinions vary on such points as the use of masks and the relative importance of other medical aseptic practices, guides often provide only basic information to be supplemented or modified by incorporation of staff opinions.

Table I

Table I lists some diseases in which the respiratory tract is an important portal of exit and entry for the infectious agent. The primary modes of transmission for these diseases is thought to be by direct and indirect contact, and/or airborne.

Column D indicates the secretions, excretions, discharges from lesions, and body fluid in which the infectious agent in specific diseases may be present (in addition to the respiratory tract and its discharges).

***Table I.*—Diseases with Primary Modes of Transmission by Airborne Particles and/or Direct and Indirect Contact with the Respiratory Tract**

Diseases	*Column A* Gown	*Column B* Handwashing	*Column C* Masks of demonstrated effectiveness. Cap if indicated (as in care of small children).	*Column D* Listing of infectious agents in body fluids, excreta, or discharges if significant in transmission.* (In addition to discharges from respiratory tract).
Anthrax	Indicated	Indicated	Mask may be recommended by medical staff.	Tissues from infected animals; contaminated wool, hides, brushes. (In addition to potential of man inhaling the spores, organisms may be present in discharges from lesions of a pateint.)
Chickenpox				Lesion and discharge
Diphtheria				Lesion and discharge
German Measles (Rubella) Influenza Measles (Rubeola) Mumps (Infectious Parotitis)				Urine
Meningitis, such as Meningococcus, Tuberculosis, and Influenza				Cerebrospinal fluid; hemorrhagic skin lesions in meningococcal meningitis
Pertussis (Whooping Cough) Poliomyelitis (also listed in Category II)			Cap if indicated (as in care of small childr[illegible]	Feces and cerebrospinal fluid
Pneumonias				

Table IIA

Table IIA cites some diseases in which the portals of entry and exit include the oral, gastrointestinal tract, and anal route, with transmission by direct or indirect contact. The infectious agent usually is in the excreta, particularly the feces.

Since patients with these diseases may become carriers and excrete the causative organism for some time after the acute illness, the practice of a modified technique may be indicated if the patient is known to comprehend and practice good personal hygiene. The importance of good personal hygiene and handwashing after toilet use should be included in the health education process for the patient to prevent reinfection and to limit spread of infection to others in the hospital and in the home and community after discharge.

Table IIB

Table IIB cites serum hepatitis as an infectious agent which may be transferred to the host by contaminated blood in a transfusion, by inoculation with a contaminated blood product, or by accidental inoculation with a contaminated needle and syringe. The organism is not thought to be carried in the feces of the patient as in infectious hepatitis.

Since it is not always possible to determine quickly if a patient definitely has serum hepatitis or infectious hepatitis, isolation technique following initial diagnosis is recommended.

Table III

Table III lists some diseases in which the infectious agent is found in lesions of the mucous membrane and/or skin, and the discharge from these lesions is transmitted by direct or indirect contact.

Table IV

Table IV lists some diseases in which the primary mode of transmission is by direct contact (sexual intercourse). On occasion, transmission may occur by indirect contact.

Patients with these diseases may become noninfectious some time after therapy is instituted.

Table IIA.—**Diseases Transmitted by Direct or Indirect Contact with Patient or Carrier, and Ingestion of the Infectious Agent**

Diseases	*Column I* Gown	*Column II* Handwashing
Amebiasis Cholera Diarrhea of the Newborn Infectious Hepatitis** Poliomyelitis (also listed in Category I) Salmonellosis Shigellosis (bacillary dysentery) Typhoid Fever	Indicated	Indicated Infectious agent in excreta* with ingestion through hand-to-mouth contact; or infectious agent in food, water, or milk supply. Also, infectious agent in blood (infectious hepatitis)

Table IIB.—**Disease Transmitted by Mechanical Inoculation (e.g., Needles, Syringes) Contaminated with Blood, Blood and Blood Products Containing Infectious Agent**

Disease	*Column I* Gown	*Column II* Handwashing
Serum Hepatitis**	Not indicated unless illness is regarded as possible Infectious Hepatitis	Indicated

*When indicated, gloves may be used for an activity in which the hands become contaminated with feces.
**Disinfection of needles, syringes, and blood-contaminated equipment prior to handling is important in preventing transmission by mechanical inoculation.

Table III.—**Diseases Transmitted by Direct or Indirect Contact With Patient; Infectious Agent on Skin and/or Lesions, on Conjunctiva, if involved, and in Discharges***

Diseases	*Column I* Gown	*Column II* Handwashing	*Column III* Cap
Conjunctivitis (acute, infectious) of the newborn	Indicated	Indicated	Indicated in care of patients, such as small children
Impetigo contagiosa	"	"	"
Ringworm	"	"	"
Scabies	"	"	"

*When indicated, gloves may be used for an activity in which hands may become contaminated.

Table IV.—**Diseases Transmitted Primarily by Direct Contact (Sexual Intercourse) or Occasionally by Indirect Contact; Infectious Agent in Affected Area, Lesions, and Discharge**

Diseases	*Column I* Gown	*Column II* Handwashing	*Column III* Cap
Chancroid	Indicated	Indicated	Indicated in care of patients, such as small children
Gonorrhea	"	"	"
Infectious Syphilis	"	"	"

The importance of handwashing should be stressed to gonorrhea patients who also must be cautioned against touching their eyes. Personnel caring for such patients should practice the same precautionary measures.

Table V

Table V includes diseases which are not thought to be transmissible person-to-person and for which various preventive and control measures are listed. Aseptic procedures, including handwashing, are used in the care of all patients.

Group A:

- Brucellosis
- Mycoses (systemic) such as:
  - Blastomycosis
  - Coccidioidomycosis
  - Cryptococcosis
  - Histoplasmosis
  - Sporotrichosis
- Leptospirosis
- Tetanus
- Trichinosis

Group B:

Toxoplasmosis apparently may be transmitted from a mother with an acute infection through the placenta to the fetus or to the infant during delivery. The method of transmission after delivery has not been definitely established. To prevent accidental mechanical transmission, precautions in the use of needles, syringes, etc., are indicated in caring for the infected mother or infant.

Table VI

Table V.—Diseases Not Transmissible Man-to-Man

Diseases such as—	Aseptic Procedures Used in Care of All Patients	Steam Sterilizing of Contaminated Needles, Syringes and Other Blood Contaminated Articles	Rodent and Vector Control Measures
Group A			
Brucellosis	Indicated		
Encephalitis			Indicated
Leptospirosis			Indicated
Malaria		Indicated	Indicated
Mycoses, systemic as:			
Blastomycosis			
Coccidioidomycosis			
Cryptococcosis			
Histoplasmosis			
Sporotrichosis			
Serum Hepatitis		Indicated	
Q Fever			
Rickettsial Pox			Indicated
Rocky Mountain Spotted Fever			Indicated
Schistosomiasis			Snail control program indicated
Tetanus			
Trichinosis			
Tularemia			Indicated
Typhus Fever, Epidemic Louse Borne			Louse control program indicated
Yellow Fever			Indicated
Group B			
Toxoplasmosis		Indicated	Indicated

This group of infectious diseases is not transmissible man to man except by accidental inoculation in some diseases and, therefore, may be cared for with the same aseptic practices as used for care of all patients in a hospital. If the infectious agent is present in the blood, needles and syringes, as well as blood contaminated articles should be cared for to prevent accidental inoculation by the infectious agent.

Table VI.—Diseases With Miscellaneous Modes of Transmission

For personnel with occasional casual contact, such as conversation, handwashing is considered adequate

Diseases such as—	*Column A* Gown	*Column B* Handwashing	*Column C* Gloves
Leprosy*	Indicated when lesions are open and for persons in repeated close contact with patient	Indicated	For activities such as changing dressings and applying packs to lesions or affected areas, etc.
Rabies**			For activities involving contact with mouth and saliva

*Infectious agent in open lesions of skin, mucosa, and discharges; portal of entry at the mucosa of the respiratory tract, skin, etc.

**Infectious agent in saliva of patient with possibility of man-to-man transmission.

HOSPITAL INFECTIONS COMMITTEE

During the middle and late 1950's, a significant increase of hospital-acquired Staphylococcal infections was occurring in hospitals in the United States, and in other countries. Concern for the prevention and control of hospital infections stimulated special studies, seminars, and conferences on identification, prevention, and control of these infections.

In 1958 the Joint Commission on Accreditation of Hospitals and the American Hospital Association jointly recommended that each hospital appoint a committee on infections, invested with responsibility to investigate infections, establish surveillance programs, and provide leadership and guidance for the prevention and control of infections.

The American Hospital Association Bulletin No. 1, *Prevention and Control of Staphylococcus Infections in Hospitals*,* distributed in 1958, has implications for prevention and control of infections caused by any pathogen. It has lost none of its pertinence today. The "recommendations" of that Bulletin follow:

I. All hospitals should establish Committees on Infections, to devote particular attention to infections which are acquired in hospitals so they may be reduced to the lowest possible minimum.

   A. It is suggested that the Committee on Infections include, where possible, a bacteriologist, a pediatrician, a surgeon, an internist, a nurse, and a hospital administrator. The local health officer should be urged to serve as a consultant to the committee. The committee should report periodically to the executive committee of the medical staff.

   B. The functions of the Committee on Infections should include at least the following:

      1. To establish a system of reporting infections among patients and personnel, such a system being essential to a proper understanding of infections which are acquired in hospitals. The committee should have access to all reports of infections anywhere in the hospital.

      2. To keep records of infections as a basis for the study of their sources and for recommendations regarding remedial measures.

      3. To distinguish to the best of its ability between infections acquired in the hospital and those acquired outside.

      4. To review the hospital's bacteriological services to make sure that such services are of high quality and are accessible either in the hospital itself or in an outside laboratory. Bacteriophage typing, if not available in the hospital, may be sought, as needed, through official local and State health agencies.

      5. To review aseptic techniques employed in operating rooms, delivery rooms, nurseries, and in the treatment of all patients with infections and, if indicated, to recommend methods to improve these techniques and their enforcement.

      6. To make vigorous efforts to reduce to the minimum consistent with adequate patient care:

         (a) Use of antibiotics, especially as "prophylaxis" in clean, elective surgery

         (b) Treatment with adrenocortical steroids

      7. T

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* This material was prepared by the Committee on Infections within Hospitals of the American Hospital Association's Council on Professional Practice. It was distributed in bulletin form on May 21, 1958, to administrators and chiefs of staffs in all hospitals that are institutional members of AHA.

hospital. Two approaches to discovering such infections are suggested:

(a) An attempt to trace the source of any infection with which a patient may be admitted. For example, if an infant is admitted with Staphylococcal pneumonia or a recently delivered mother with mastitis, the hospital where delivery occurred should be determined and informed of the infection so that it can seek possible sources of infection.

(b) Periodic telephone polls on a random sample of discharged patients (particularly recently delivered mothers, newborns, and postoperative patients) to ascertain their state of health and, in case of any indication of infection, to follow them up. Such surveys have proved simple and valuable.

II. Hospital administration should undertake the following measures to assist in the control of infections:

A. Diligent maintenance of the general cleanliness of all areas in the hospital, not simply those associated with operating rooms, delivery rooms, and nurseries. Other possible sources, such as dust, air pollution (special attention should be given to ventilating and air-conditioning systems and their filters), and floors must also be considered as potentially important factors in the spread of infection. There should be regular inspections of the hospital for general cleanliness.

B. Special studies among staff and personnel to uncover silent carriers of Staphylococcus, especially in epidemic situations accompanied by repeated cases traceable to the same organism.

C. Appropriate measures for the treatment of all carriers who persistently show heavy growth of epidemic strains of staphylococcus in naso-pharyngeal cultures or who are identified by epidemiological evidence.

D. Transfer of such carriers and personnel with skin infections, boils, acute upper respiratory infections, and the like from locations such as operating rooms, delivery rooms, food-handling positions, and nurseries to other duty stations in the hospital. Usually such transfers have proved to be sufficient to control the problem, but occasionally leave of absence for a persistent carrier has been necessary.

III. Hospitals should initiate or participate in community programs to control infection through cooperation with other hospitals, local medical societies, local health departments, and other groups.

A PROGRAM FOR PREVENTION AND CONTROL OF INFECTION

An effective program for prevention and control of infections in hospitals necessitates consideration of:

1. Standards, recommendations, and requirements of the Public Health Service, State and local health departments, and other organizations, such as the American Hospital Association, and American Academy of Pediatrics
2. Infections committee responsibilities
3. The hospital population
   a. Patients
   b. Hospital personnel
   c. Students
   d. Visitors
   e. Volunteers
   f. Persons delivering items to patients
4. The physical environment and facilities
5. Environmental sanitation
6. Aseptic practices and procedures

The Hospital Population

Patients. At the time of admission, recent exposure to infectious disease and/or the presence of any communicable illness in the family should be ascertained. The physical examination at the time of admission and care of each patient during hospitalization should stress alertness to the possibility of an existing infection.

Appropriate preventive measures should be considered as early as possible in the care of the

If physical examination or patient his-
.cates that he has an infection, or may be
cubation period of an infectious disease,
nunization, chemo- or antibiotic-prophy-
.d/or isolation may be indicated by the
ı.

›atient's plan of care should include health
as indicated by the nature of his disease.
ching will help reduce the patient's poten-
lisseminating pathogens person-to-person
the environment.

ıd patients should be informed by the
ı, or by a nurse after consultation with
ician, of the need for medical aseptic tech-
An understanding of the reason for such
should aid in decreasing the feeling of
which isolated patients often experience
ıld help to secure their cooperation in
eventive practices. Such patients should
ority in the use of radio and television
questing the assistance of the family in
g for diversional needs of isolated pa-
lesirable both in its primary purpose and
eling of satisfaction the family usually
rom participating in the care plan.

d patients may sense the pressure person-
ı feel in the practice of medical aseptic
es, which are time-consuming and disrupt-
utine work. It is important that the plan
ncludes consideration of this time factor
assignment of personnel with ability to
additional needs of isolated patient care.

al Personnel. Personnel and medical staff
ıospital departments play the central
he prevention and control of infections.
ı the maximum contribution from them,
›wing should be considered:

recruiting, selection, and assignment of
most competent personnel available based
attitudes, interests, and specific job
ities

ıpetent supervision

›reventive health program for personnel

orientation and staff education program

nel of all departments should be selected
ned in relation to their interests, abilities,
ıtial for assuming responsibility.

ientation, staff education, and training
s should emphasize:

1. Importance of personal hygiene and health status in control of infection
2. Alertness to possible symptoms of infection in patients as well as in themselves (skin eruptions, boils, diarrhea, sore throat) with prompt reporting to immediate supervisor
3. The principles of asepsis and their application

Thoughtful and skillful supervision is essential to good performance and adherence to established standards and practices.

A preventive health program for employees is especially important in institutions where there is continual exposure to pathogens in the performance of their work. Such a program will not only improve their health, with less time being lost from work because of illness, but also should provide for early identification of an infection and prompt use of measures to prevent its spread.

While hospitals will vary in preventive health program coverage, each should provide for some basic health services to its personnel. Such services should include:

1. *Preemployment Physical Examination.* Such an examination should include laboratory procedure and X-rays, if indicated. When an infection exists at the time of employment, the employee should have the opportunity to secure medical care. Assignment to duties should be postponed until he is free from infection. An infection present at the time of employment may have legal implications in relation to compensation determinations.
2. *Immunizations.* While recommended immunizations may vary by geographical area according to illnesses occurring within that

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3. *Administration of gamma globulin if indicated.* Consideration should be given to administration of gamma globulin as protection for:

   a. Employees exposed to gastrointestinal discharges or blood of patients with infectious hepatitis or who may suffer accidential puncture wounds by needles or objects used in the care of these patients

   b. Employees who lack known immunity to measles or German measles and who are exposed to these diseases in the hospital. (Female employees in the first trimester of pregnancy who lack immunity to German measles should receive gamma globulin)

4. *Medical consultation for personnel with symptoms of infection.* Personnel having symptoms of infectious diseases (diarrhea, skin eruptions, furuncles, boils, sore throats) should have a medical consultation for diagnosis and treatment. Encouraging staff to secure consultation when symptoms are noticed may prevent spread of the infection to others and limit the disease pathology in the employee. Personnel with such symptoms should not be approved for return to work except by the examining physician.

Students. Students having clinical experience in hospitals concomitant with their educational pursuits in medicine, nursing, or occupational or physical therapy should be covered by the preventive health program. They should also have an educational program in prevention and control of infections, with supervision of their practices. It is important that the educational institution and hospital jointly determine responsibility for these considerations, so students will have a preventive health program and supervised clinical learning experiences.

Since many students in the medical and paramedical fields will be future hospital employees or staff members, it is paramount that their education include practical application of measures to
-l control hospital infections. Their
nd future leadership in the broad area
control have important implications
quality.

.tors should be informed of their
ospital's infection prevention and
. Their understanding is vital to their cooperation. Visitors should know that they are expected to conform to policies and procedures when visiting patients.

Instruction should include:

1. Observation of hospital policies and procedures when visiting patients.
2. The practice of thorough handwashing, and techniques such as gowning when visiting patients with infections or with high susceptibility to infections.
3. Persons who have infections or have been in contact with infected persons should not visit patients.

While visiting policies will need individualized consideration, adults, especially those in the immedate family, may often be permitted to visit patients with an infectious disease. This includes pediatric patients. In most instances, parents should be encouraged to visit their children and to participate, when possible, in their care program.

In communities having an appreciable number of infectious disease cases with serious implications for the ill, the health department or hospital administrative staff may institute a temporary policy of restricting hospital visitors.

The attending physician may also recommend restricted visiting for a patient with significant susceptibility to an infectious disease. Generally, such restrictions provide for visiting only by members of the immediate family.

Volunteers. While volunteers should be taught some principles of aseptic techniques, such as the importance of handwashing in activities involving any patient, they should not be permitted to enter the room of a patient isolated with an infectious disease. Volunteers should have sufficient knowledge of symptoms indicative of possible infections in themselves to stay out of the hospital if infected and to secure medical consultation as indicated.

Persons Delivering Items to Patients. Hospital policies related to privately employed persons delivering items for patients, such as flowers, merit thoughtful consideration. Delivery people should have no opportunity for direct contact with patients, especially infectious disease cases and others with susceptibility to infection. Delivery of items at a receiving desk, with subsequent delivery to the patient by a hospital employee, eliminates the need for direct patient contact by such persons.

ASEPTIC TECHNIQUE IN CARE OF ALL PATIENTS

Aseptic practices in the care of all patients encompass many aspects of care as well as those of environmental control. Examples follow:

1. Screening of a patient for an infectious disease or for the presence of an infectious disease in the patient's family. Special room assignment and use of isolation technique may be instituted to prevent spread of infection to other patients or personnel.
2. Use of clean, freshly issued supplies and equipment for each patient. A clean unit and/or room with necessary supplies (blankets, bath basin, emesis basin, etc.) should be provided each patient. Equipment being used repeatedly by the same patient should be frequently cleaned and decontaminated or sterilized, if necessary. Equipment such as heating pads, nebulizers, and oxygen tents used by a number of patients should be cleaned and decontaminated after each use by an individual patient.
3. Administration of patient care, either direct or indirect, only by personnel who are themselves free from infection.
4. Handwashing before and after any contact with a patient. Unless care personnel wash their hands thoroughly before and after any activity, they may contaminate clean or sterile supplies and equipment or spread pathogens directly or indirectly to the patient and others.
5. Proper sterilization and decontamination of supplies and equipment.
   a. A central medical and surgical supply service is conducive to use of standard procedures for cleaning, preparation, decontamination, and/or sterilization of supplies and equipment.
   b. Evaluation of sterility of supplies and equipment should be performed routinely by the hospital bacteriologist.
   c. Storing infrequently issued supplies and equipment in closed cabinets helps prevent contamination.
   d. Instruments and equipment to be decontaminated may be wrapped or placed in a protective container clearly identified as "contaminated" for return to central medical and surgical supply. Such handling will prevent contamination of the environment in transit and identify contents as hazardous to personnel. Such contaminated items also may be decontaminated on a nursing unit or other area which provides a steam sterilizer or ethylene oxide sterilizer.
   e. Frequent cleaning and decontamination of equipment, floors, and furnishings and proper disposal of contaminated materials minimize contamination of the environment and the potential infection of patients or personnel.
6. Care in the distribution of supplies. Dressing or surgical carts, if used, should be utilized as a supply source for individually packaged dressings and similar items which can be stored in covered containers. Such carts should *not* be taken into the patient's room, nor should they include a container for disposal of soiled dressings. Single-use vials and bottles of sterile solutions and medications are preferable to multiple-use containers.
7. Provision for facilities and equipment to separate clean and dirty procedures and items:
   a. When dumbwaiters or carts are used for returning supplies to central medical and surgical supply, some should be designated for return of used equipment and others for distributing clean or sterile equipment. They should be cleaned daily, or more

8. Maintaining the environment as clean as possible. This can be enhanced by:
   a. Good housekeeping practices
   b. Providing the patient with clean bed linen, blanket, and clothing as often as indicated to aid in removing pathogens from his immediate environment
   c. Removing soiled linen from the bed, and rolling the most contaminated side innermost with a minimum amount of motion, which helps prevent dissemination of pathogens and saves time
   d. Teaching patients the proper use of paper wipes when they cough, sneeze, and expectorate, and to discard used wipes directly into a moisture-proof bag
   e. Teaching the patient good personal hygiene such as thorough bathing and handwashing to reduce opportunity for self-infection, or reinfection, and infection of others
   f. Discarding soiled dressings directly into a moisture-proof bag at the point where the dressing is removed, and securely closing the bag until removed for incineration
   g. Minimizing physical activities in any area when sterile procedures are being performed, such as removal and application of dressings or performance of surgical procedures.

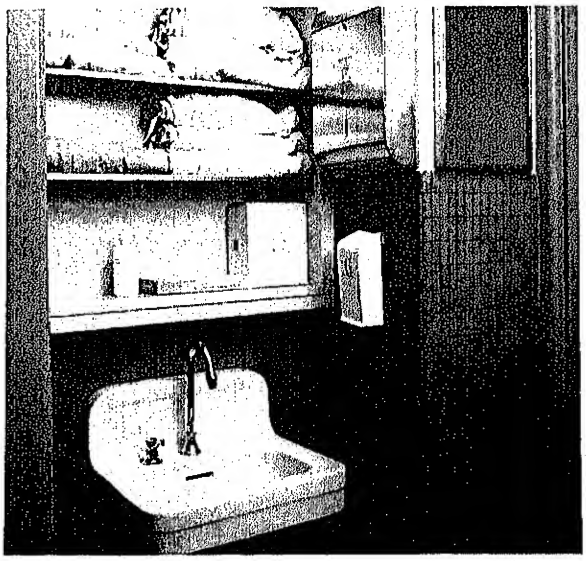

Figure 2.—**Entry cubicle to isolation room showing foot-operated handbasin, soap, disposable towels, sterile gowns, and disposable masks.**

ENVIRONMENTAL CONTROL FUNDAMENTALS IN ISOLATION CARE

Care of an isolated patient requires an especially analytical approach by the administrative and supervisory staffs to identify care problems, to apply the best methods to correct them, and to constantly train and improve personnel. (Fig. 2.)

Basic environmental factors are:

1. Air-conditioning and protection
2. Food service and sanitizing of dishes
   a. Ordering, inspecting, storing, and preparing food.*
   b. Sanitizing dishes, utensils, trays, and water carafes

Since food and drink service items from all patients and hospital personnel must be sanitized after each use, it is important that mechanical dishwashers meet appropriate performance standards.* In addition, procedures must provide for the proper use of such equipment.

The area where dishes are scraped and prepared for racking should be physically separated, if possible, from the area where clean dishes are processed. Personnel procedures and daily supervision should emphasize frequent handwashing for all dishroom personnel. This point cannot be overemphasized where there is no separation of clean and dirty areas and where the same personnel scrape and rack dirty dishes and unload clean dishes from the machine. Any trained employee who goes directly from the dirty end of the dishwasher to handle clean ware without thoroughly washing his hands should be dismissed or reassigned immediately. There is no reason to tolerate such potentially dangerous carelessness by any employee who has been made aware of the dangers of contaminated food service utensils.

If a supervisor notices such negligence, the items that have been mishandled should be run through the dishwasher a second time.

Trays and dishes from patients with communicable diseases may be encased in a moisture-proof bag to prevent contamination of the environment while the trays and dishes

*See, chapter IV, vol. II, Environmental Aspects of the Hospital.

are in transit and until processed in the dishwasher. In cases of respiratory diseases, during epidemics of any variety of infectious disease, or during acute shortages of personnel, disposable dishes for patients are recommended. For other categories of infectious disease patients, since dishes can be easily sanitized, and isolated patients often have significant nutritional requirements, efforts should be made to keep dietary procedures as near normal as possible, consonant with disease control. (Figs. 3a, 3b, and 3c.)

c. Serving food to the isolated patient

Dietary personnel should not deliver trays or remove them from the room of a patient with a communicable disease. A dietary aide may bring the tray to the door of the isolation room and a nursing aide may serve the tray to the patient, using medical aseptic precautions as indicated.

3. Housekeeping

Good housekeeping provides the greatest contribution in removing pathogens from the environment. A thoughtful plan which cleans all areas systematically and at additional times when indicated is essential to effective housekeeping. Daily cleaning of patient care areas is basic, with removal of contamination as soon as possible after it is deposited. Cleaning of certain areas may be indicated before reuse. In addition to such routine care for operating suites and delivery rooms, treatment rooms should be decontaminated after care is given to a patient with an infectious disease.

After discharge of a patient, his room should be cleaned thoroughly. Such terminal cleaning and disinfection should include, in addition to furnishings, fixtures, and surfaces, areas liable to repeated hand contact such as light switches and door and cabinet handles. If plug-in telephones are used, these should be decontaminated and, if possible, sterilized by gaseous sterilization. TV and radio sets used in isolation units can be wiped off thoroughly with 70 percent alcohol or sterilized by gaseous sterilization (see table

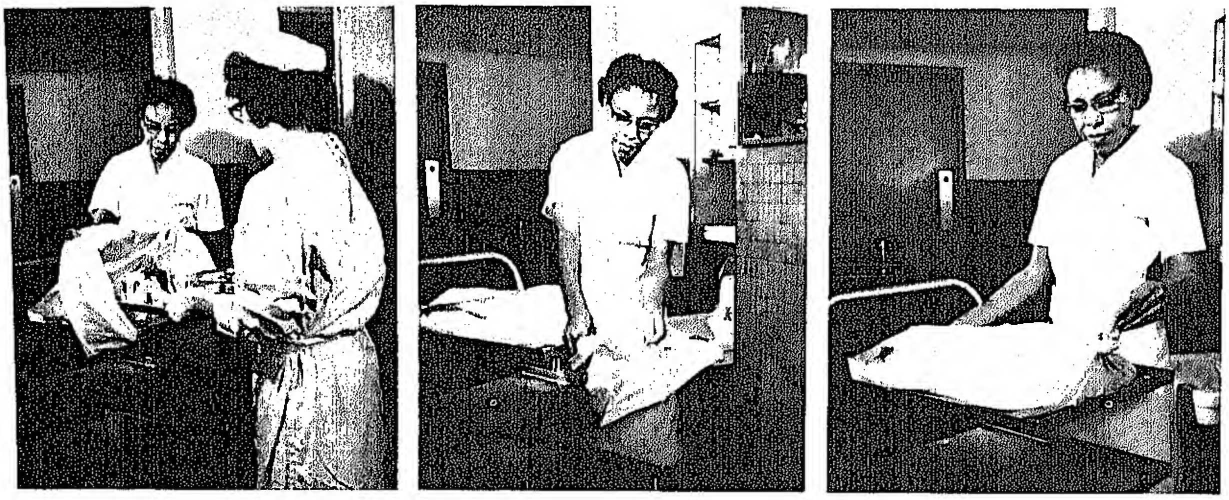

Figure 3a.—Diet tray of isolation patient is placed into plastic bag to be transported to dishwashing area. *Figure 3b.*—Tray bag is sealed. Note ample length of bag to permit effective sealing. *Figure 3c.*—Tied bag ready for return to dishwashing area.

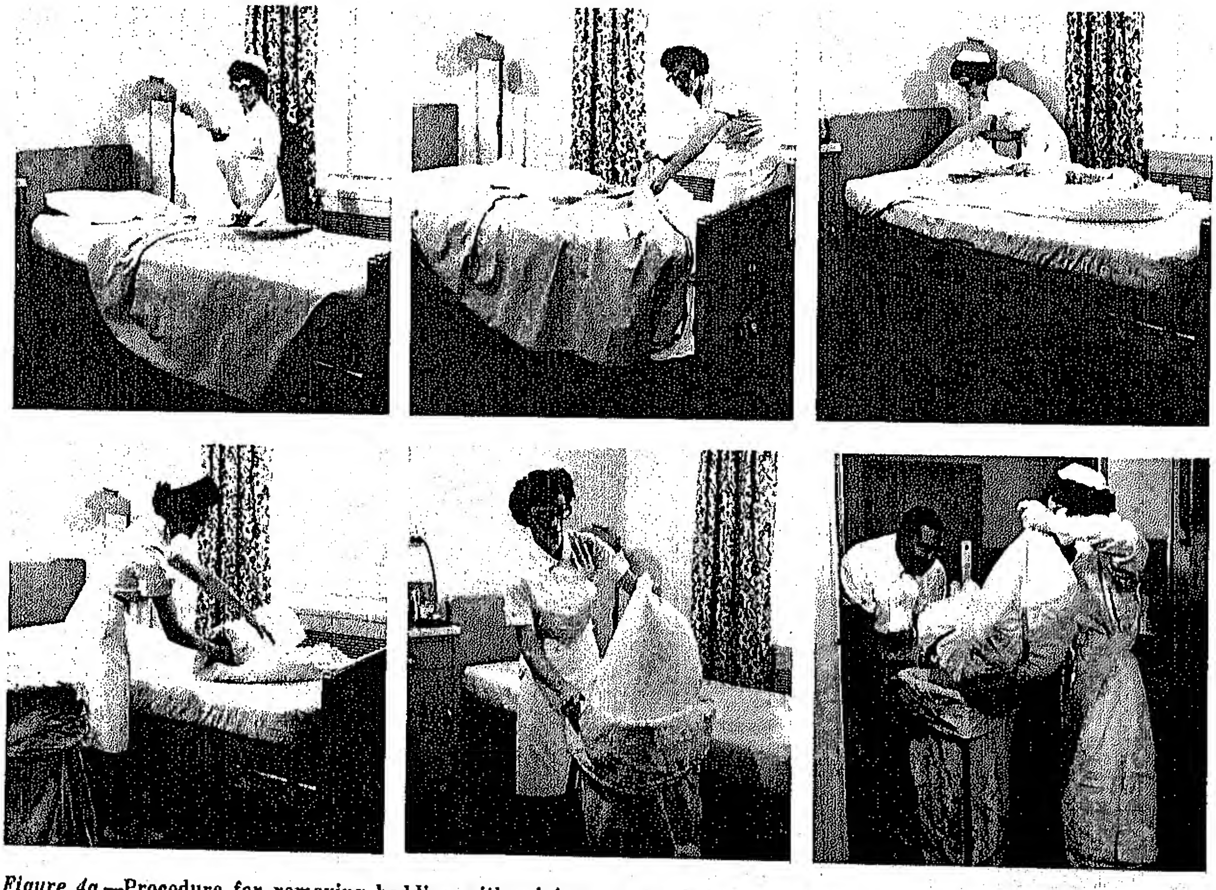

Figure 4a.—Procedure for removing bedding with minimum aerosol generation. *Figure 4b.*—Sheet is loosened at foot of bed and folded toward center. *Figure 4c.*—Sheet is loosened at top of bed before rolling to center. *Figure 4d.*—Used bedding is rolled. *Figure 4e.*—Rolled used bedding is placed into color-coded laundry bag. *Figure 4f.*—Double-bagging by placing "room" bag into color-coded outer bag (for isolation linen).

VII). Radiators, air-conditioning outlets, light fixtures, rugs, draperies, and venetian blinds should be cleaned during the regular cleaning schedule and otherwise when indicated.

4. Proper disposal of soiled linen and refuse

A hamper bag and waste basket in the patient room provide for easy disposal of soiled linen and refuse at the site of contamination.

a. A hamper bag should be available near the door of the patient's room for his soiled linen, staff gowns, and other clothing used in the room. The use of colored hamper bags for collecting linen from patients with communicable diseases identifies this linen.

As in the care of all patients, soiled linen should be rolled with the most contaminated side innermost and with minimum amount of motion. Moist linen should be placed in the center of a bundle of linen in the center of the hamper bag to prevent penetration of moisture through the bag. If indicated, wet linen may be placed in vinyl bags prior to placement in the hamper bag. In any case, moist linen should be laundered as soon as possible after collection.

Hamper bags of soiled linen from the room of a patient with an infectious disease should be inverted into a second hamper bag (double-bagged) to minimize contamination of the environment when the linen is being transported to the laundry. (Figs. 4a, 4b, 4c, 4d, 4e, and 4f.)

b. A waste basket with a moisture-proof closable liner should be available in the patient's room. Such a bag can be closed and placed in a larger container preparatory for incineration. The waste basket should be metal to permit decontamination method of choice depending on disease.

5. Monitoring of the environment

A plan for ascertaining the degree of cleanliness and specific pathogens present in various areas of the hospital, including the atmosphere, provides an index of success of the aseptic techniques in effect. Such an evaluation also provides clues to problem areas and to successful practices.

6. Handwashing

Handwashing is of primary importance in preventing the spread of infection. While caring for all patients, particularly those with

Figure 5a.—**Careful gowning with proper overlap closure should be done prior to masking.**

Figure 5b.—**Four-string gauze mask.**

Figure 5c.—Molded contour mask.

Figure 5d.—Bonded fiberglass mat mask with nasal contour strip.

infectious diseases, handwashing should be practiced after direct or indirect contact with patients. In addition, the practice of handwashing by patients is important as a preventive measure to self-infection and the infection of others, as well as to reduce contamination of the environment. Handwashing facilities for staff should be conveniently placed in care areas.

All personnel with patient care responsibilities should be informed of the isolation technique or protective measures in effect for specific disease categories. Employment of specific techniques will depend on diagnosis, either presumptive or confirmed; the etiologic agent, its virulence and susceptibility to destruction; the mode of transmission; and the portals of exit and entry. Knowledge of the significance of these factors will enable staff to proceed in a purposeful manner. (Figs. 5a, 5b, 5c, and 5d.)

Specific nursing and medical procedures in communications, apparel, and other aspects of maintaining aseptic control of the environment can be found under "References" and "Additional Reading" at the close of this chapter.

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Chapter V

DECONTAMINATION AND STERILIZATION

Lloyd G. Herman

With modern chemicals, equipment, and methods, proper decontamination minimizes the hazards of indirect transmission of disease to patient and worker more effectively than ever before. In its broadest sense, decontamination is the physical or chemical process for freeing any given surface or article from all undesirable inert matter, chemicals, or viable microorganisms to the point where the contamination is no longer a hazard. Sterilization, of course, constitutes the complete removal of all contaminants.

SOURCES OF CONTAMINATION

The principal source of hazardous contamination in the hospital is generally considered to be man himself. Wastes from his own life processes, such as urine, feces, respiratory aerosols, and minute flakes of skin, are continuously being generated and distributed. To these basic contaminants, an ill individual may add the residues and secretions from diseased tissues. Many pathogens in the inanimate environment, such as molds, yeasts, and many of the Gram-negative pathogens, are carried into the hospital and distributed during the movements of the hospital population. In comparison, pathogens brought into the hospital in food, water, air, or on various fomites are proportionately secondary to those either emitted or transported by humans.

Some of these pathogens are quite fragile and do not survive for long in the physical environment. Others endure, adapt for extended periods of time, and require rigorous measures for their removal or destruction.

The following four factors should be remembered about decontamination and sterilization procedures:

1. The reliability of any sterilization process is largely dependent on the thoroughness of the decontamination which precedes it.
2. When decontaminating any surface, including the human skin, it is just as effective to remove pathogens in a safe manner by washing or cleaning as it is to kill them *in situ* with chemicals, and is usually easier on the surface concerned.
3. In most decontamination work, the one indispensable element needed to make effective use of cleaning compounds and detergents is friction, whether applied by machine or by the human hand and arm.
4. Cleaning materials such as mop heads, cleaning cloths, and the like should be replaced freqently with clean items. The object is to remove soil, not rearrange it.

Inhalation Therapy Equipment

Anesthesia units, face masks, resuscitators, oxygen tents, humidifying units, and special incubators are usually used for extended periods of time and are often simply wiped off with a damp cloth before being reissued for use by another patient. The accumulated moisture remaining in many of these units after use encourages the growth of pathogenic bacteria which can be readily transferred from patient to patient. (Fig. 6.)

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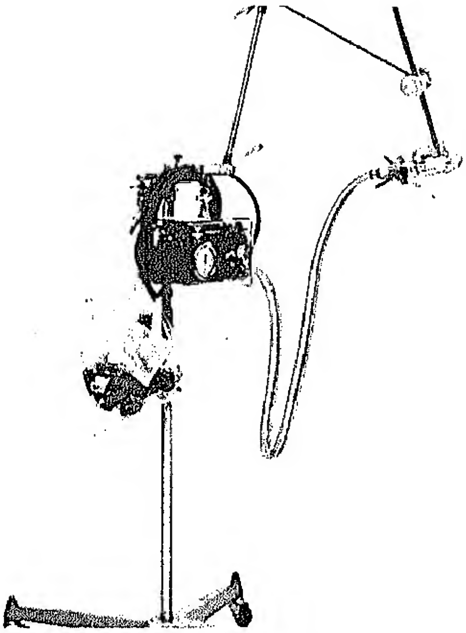

Figure 6.—**Respirator unit with sterilized patient-contact components in sealed plastic bag prior to delivery to using area.**

Decontamination. All reusable inhalation therapy equipment should be disassembled after each use or after a maximum of 5 to 7 days of continuous use by the same patient. The smaller

Figure 7.—**Wrapped inhalation therapy assemblies in "ready room" after sterilization. Storage areas should be clearly labeled, clean, and well lighted.**

parts may be placed in an automatic dishwasher, washed with low-foaming detergent-sanitizer, and thoroughly rinsed with clear water. The larger parts may be washed by hand with the same sanitizer solution and rinsed. At no time should residual cleaning solutions be left on this type of equipment, since their contact with the patient's skin may result in irritation.

Sterilization. Before reassembly, any broken or worn parts are replaced and the whole unit properly wrapped and autoclaved. If heat sensitive, the unit should be placed in a 1 mil plastic bag, sealed, and sterilized with ethylene oxide for the recommended time and temperature. The items are then stored in a clean area for reissue.* For heat-destructible items used in institutions where no gaseous sterilization equipment is available, conscientious use of chemical agents as outlined in Appendix B should be followed. (Figure 7.)

Dressing Equipment

Since more and more disposable equipment and materials are becoming available, direct transfer of infection from patient to patient may become somewhat easier to control. Such common items as the surfaces of dressing instruments and medication containers are sometimes overlooked, however, and unless adequate care in handling is practiced, patients and staff may be unnecessarily exposed to pathogenic organisms.

Decontamination. As instruments are used they should be deposited in an impervious, covered container. Discarded dressings and other contaminated wastes should be placed in plastic bags, sealed, and placed in a special collection can for direct transfer to the incinerator. In isolation areas, the dressing tray should not be moved out of the room until the patient is discharged. Following the daily dressing rounds, all instruments used in changing packs and dressings should be soaked in a suitable disinfectant solution (or steam-sterilized if sterilizers are available on the patient care unit) before being returned to central medical and surgical supply to be cleaned, rewrapped, and sterilized. The need to protect nonprofessional staff members, as well as patients and professional staff, must never be overlooked.

Sterilization. All such instruments and equipment from the patient care area should be checked in and out of the central medical and

*No cultures of *Pseudomonas*, *Proteus*, *Streptococcus* or *Flavobacteria* have been isolated from ready-for-issue inhalation therapy equipment since this procedure has been adopted in a large hospital.

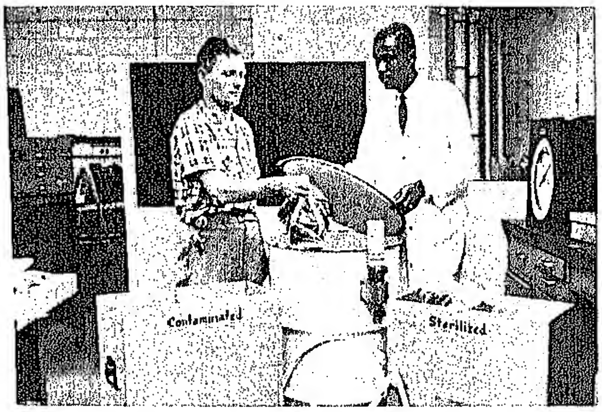

Figure 8.—Patient telephones being disinfected after patient is discharged.

surgical supply service (CMSSS) to guarantee proper cleaning, inspection, wrapping, and sterilization before reissue to patient care units. Any sterilization done on patient care units should be under the surveillance of CMSSS staff to insure uniform practices and control of all items. (Fig. 8.)

Medication, Food, and Water

Since everything coming in contact with a debilitated patient is always suspect, adequate control measures must be observed to insure proper aseptic precautions. Contaminated ice and improperly sanitized dishes have caused needless suffering, while improperly stored or handled food has carried lethal infections. Drinking water and other liquids kept in bedside carafes also provide nutrients for the rapid growth of many pathogenic organisms, unless these containers are cleaned and refilled daily.

Decontamination. All multiuse utensils for food, drink, or medication, except those used in some isolation cases, should be taken to the central food service or cleaning area where adequate dishwashing facilities are available.

Sterilization. Where isolation procedures for respiratory and some enteric diseases are required, the use of disposable paper or plastic containers is usually more economical and safer. However, with normal patients the routine handling of reusable items in the kitchen is usually adequate when conscientiously performed. In the case of foods, it is not so much a problem of original sterility as preventing growth of accumulated organisms during storage, preparation and handling, hence the need for adequate temperature control of all potentially hazardous foods and liquids at all times.

Laundry and Linen Handling

Since man, healthy or ill, is constantly shedding particles of skin, the pajamas and bedding of patients are usually heavily contaminated. Great care must then be taken in handling the bedding and removing it from any patient area. Color coding of bags for carrying various types of washable articles to the laundry will do much to simplify limiting the spread of contamination. Similarly, utmost precaution is necessary to prevent the recontamination of clean linen until it is returned for use by a patient.

Housekeeping Procedures

These involve the patients' entire environment and extend throughout the hospital. A well-trained executive housekeeper is a key individual in providing a sanitary environment, through directing the proper use of the right equipment and materials by trained workers. Since any patient with an infectious respiratory disease can conceivably contaminate the environment throughout a building, constant precautions must be taken to insure that such patients, when identified, are properly isolated. This is especially important when tuberculosis or respiratory virus is present. Ambulatory patients, visitors, and staff are often a greater problem, since they can spread infectious agents by direct contact.

Decontamination. Most airborne dust and skin particles and aerosol droplets eventually land on horizontal surfaces throughout the building. Soil and dust should be removed with a damp cloth or mop wrung out in an effective disinfectant solution. Only in this way can the dispersion of microorganisms, especially those on the floor, be prevented and contamination levels controlled. Buffing of floors, when required, should always be strictly supervised to minimize excessive dust distribution. The more frequently it is possible to clean patient care areas, the better the removal of deposited organisms. Routine damp cleaning will remove most loose soil, dust particles, lint accumulation, and similar particulates on surfaces, thus

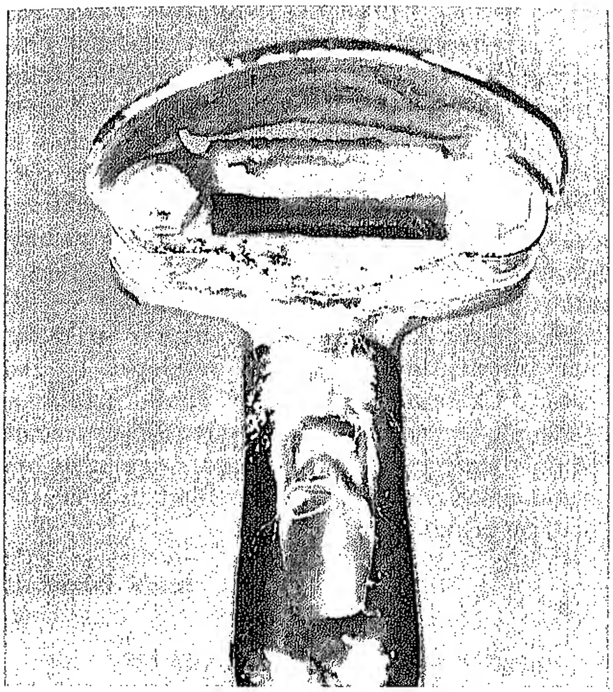

Figure 9.—**Drinking fountain bubbler, showing buildup of scale and slime. Proper cleaning and disinfection of such common equipment is vital in controlling disease spread.**

preventing the contamination from becoming airborne or being picked up and transferred by shoes and cart wheels. Scrubbing and sanitizing of corridors may be done at less frequent intervals than patient rooms, with solutions of detergent-sanitizer in a mechanical scrubber and wet vacuum pickup machine. Scheduling is dependent on the amount of traffic, the degree of deposited soil, and the species of microorganism if in an isolation area.

All horizontal surfaces, especially those close to the patient such as table tops, bed frames, and floors, must be kept scrupulously clean at all times. If the patient is a "shedder" of pathogenic organisms, these surfaces quickly become heavily contaminated and may be the source for dissemination to other rooms. The same critical care also must be applied to hand basins, toilet seats, and bath tubs. Spillage of soiled dressings or other heavily soiled wastes on the floors is especially dangerous unless immediately cleaned up and the area properly decontaminated by scrubbing with an effective disinfectant. (Figure 9.)

Cleaning procedures for critical areas such as operating and delivery rooms, intensive care units, and nurseries should be determined by the respective supervisors in consultation with the housekeeping department. Which cleaning operations are to be performed by nursing or other staff, and which by housekeeping, are a matter for local determination. The cardinal point is thoroughness in the use of effective cleaning procedures, regardless of who carries them out.

Sterilization. The housekeeping department cannot sterilize the objects under its jurisdiction in the usual ways. However, with good supervision and proper equipment and materials, all surfaces touched by patients or workers can be adequately decontaminated at regular intervals, thereby preventing a dangerous accumulation of infective residues.

Materials. All materials essential to good housekeeping such as soaps, synthetic detergents, abrasives, waxes, and polishes should be selected on the basis of a performance rating. The cost of materials are a minor item in the overall expense of cleaning and are usually a small percentage of total housekeeping budgets when related to wages and salaries. The hospital laboratory, when available, can help in the purchase of these items by comparing results through careful analyses of Association of Official Agricultural Chemists cylinder tests.

Equipment. All mechanical equipment in a hospital or nursing home must be kept scrupulously clean. When employees take pride in their equipment, they usually know how to use, maintain, and store it properly. In hospitals where more than one shift uses the same equipment, it is even more important that it be properly maintained. In heavily contaminated areas, such as isolation areas or those with routinely heavy soil deposits, or where frequent cleaning is required, extra cleaning equipment should be available to avoid moving units except for repairs.

Decontamination and Sterilizing Techniques. Much has been said and written on various types and formulation of bacteria-killing materials whether in the form of liquids, rays, gases, or steam. No one type can do all the work required in even a small hospital. The various substances intended to be used in aqueous solution to decontaminate surfaces or equipment have undesirable properties as well as advantages.

The use of simple soap or synthetic detergent solutions is usually satisfactory for office cleaning

needs. However, they are relatively ineffective in preventing the spread of living organisms from a soiled to a clean surface, especially when applied with a floor mop. The addition of a disinfecting compound to a cleaning solution may kill moderate numbers of organisms on the floor during the damp-mopping procedures, but most are killed in the mop bucket. No water-soluble chemical is active in the dry state against microorganisms, and actually very little of the disinfectant solution is ever left on the floor either during or following damp mopping. Hence, the killing activity must take place in the bucket. In critical areas such as operating rooms, the floors should be flooded with an active disinfectant solution followed by thorough scrubbing, and the solution picked up with a wet vacuum cleaner after a 3- to 10-minute exposure period. In patient care areas where wet vacuum is impractical, a precaution helpful in preventing the spread of pathogenic organisms from one surface to another is the use of a second bucket into which the residual water in the mop or cloth is wrung after mopping or wiping any soiled surfaces. This method keeps the cleaning solution much cleaner, and there is little or no opportunity to use soiled water, since it is rapidly transferred to the dirty bucket.

Appendices A and B to this chapter are taken from informational materials developed by the State of California, and by Dr. Earle Spaulding of Temple University, respectively. They are not the only such summary treatments available but provide good coverage of the subject in sufficient detail for general use.

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CLEANING, DISINFECTION, AND STERILIZATION

PHYSICAL METHODS OF CLEANING, DISINFECTION, AND STERILIZATION

A. Moist Heat

1. Saturated Steam (steam under pressure). Of all the various methods of sterilization, moist heat in the form of saturated steam under pressure is one of the most dependable. The term "saturated steam" means that the steam exerts maximum pressure for water vapor at a given temperature and pressure. This method has become almost the universal method of sterilizing surgical materials, particularly textiles, enamel ware and rubber goods.

a. Principles of "steam under pressure":

(1) Moisture and heat must always be present for effective sterilization.

(2) Through the use of "steam under pressure," it is possible to attain higher temperatures than is possible with steam at atmospheric pressure.

(3) The "autoclave" is a closed chamber into which steam is applied under pressure.

(4) Temperature is measured by the presence of a thermometer in the discharge line of the chamber.

(5) For effective sterilization, the heat must penetrate the center of the load within the chamber.

b. Advantages of "steam under pressure":

(1) The process is fairly rapid.

(2) Sterility is easily achieved. The process is effective in that it destroys all living organisms. Even dry resistant spores are destroyed upon relatively short exposure.

(3) It is not toxic and leaves no residue on the materials subjected to the process.

(4) It can be applied to many (not all) types of materials and, if used properly, does not cause deterioration.

(5) It is easily controlled.

(6) The results can be measured.

(7) Initial equipment is expensive, but the operation after installation is fairly economical.

c. Disadvantages of "steam under pressure":

(1) Specific and well-engineered equipment is required.

(2) Effectiveness is dependent upon correct operation of the equipment.

(3) The process cannot be applied to all materials. Anhydrous oils, greases, powders and other substances which are not easily permeated with steam cannot be sterilized by this process. Sharp edges of some instruments are also dulled by this method.

(4) Unless air is completely eliminated from the chamber at the beginning of the process, sterilization is prevented.

(5) Effectiveness is dependent upon correct methods of packaging and proper arrangement of load in the autoclave chamber.

d. Factors which influence effectiveness of the process:

(1) Time

(a) It is necessary to know the time-temperature relationship needed to insure destruction of the most resistant forms of microbial life.

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(b) In a given temperature, it is necessary to determine the required period of time for sterilization, including time for penetration of each article or package to be sterilized. An additional period of time should be allowed for a margin of safety.

(2) Temperature

(a) The most suitable temperature must be determined for each type of material to be sterilized. It has been proven that a temperature of 121°–123°C. (250°–254°F.) is probably optimum for a standard. There appears to be no value in going beyond this temperature in the standard pressure steam sterilizer.

For emergency sterilization, a specially designed sterilizer known as a "high speed" sterilizer, built to withstand higher pressures and temperatures, may be used to acquire sterilization. Temperatures of 132°C. (270°F.) may be applied in this type of equipment.

In the high prevacuum sterilizer, temperatures as high as 135°C. (275°F.) can be obtained.

The temperature must always be related to the pressure which is applied in the sterilization process.

(3) Pressure

(a) The most suitable pressure must be determined. The standard pressure steam sterilizer is usually designed for a maximum operating pressure of about 19 or 20 pounds per square inch, although some pressure sterilizers are built to operate at 30–35 pounds per square inch.

Here, too, pressure must be related to temperature in establishing standards for effective sterilization.

(4) Saturated Steam

(a) Heat and moisture, not steam, are the necessary requisites for thermal destruction of bacteria. The presence of steam under pressure raises the temperature to a higher degree than would be possible under normal atmospheric pressure.

(b) Saturated steam heats materials and permeates porous substances by the process of condensation.

(c) Since saturated steam cannot undergo reduction of temperature without lowering pressure nor can the temperature be increased without increase in pressure, saturated steam at a certain temperature or certain pressure is always the same.

(d) Superheated steam occurs when a volume of saturated steam with no liquid water is heated to a temperature above that of saturated steam at the same pressure. Superheated steam is not effective in the sterilizing process. It may be greatly reduced by:

i. Retaining the temperature of the steam in the jacket at a lower temperature and pressure than that in the chamber.

ii. Using only freshly laundered fabrics.

iii. Avoiding preheating surgical packs in the chamber, having steam only in the jacket.

(5) Removal of Air from the Chamber

(a) Air must be evacuated from the chamber when the steam is introduced into the chamber.

i. Retention of air will produce variations in temperature in the various parts of the chamber.

ii. Retention of air reduces the temperature of the steam in the chamber by preventing saturated steam from entering and occupying the same space in the chamber.

(6) Packaging

(a) The size and density of the package should be such that complete and uniform penetration with a liberal margin of safety will be achieved in 30 minutes at 121°C. (250°F.).

(b) The largest packs should not exceed 12″ x 12″ x 20″ in size. If a larger quantity is desired than can be accommodated in this size pack, it should be divided into two packs.

(c) Packs should be wrapped loosely and arranged to promote free circulation of steam into the center of the pack. Dense packs are hazardous in that they do not permit uniform penetration of the steam.

(d) The wrapper or protective cover on the outside of the pack provides protection against contact contamination after sterilization, as well as acting as an effective dust filter and guarding against entry of insects or vermin.

i. Double thickness of unbleached muslin appears to be the best wrapper. It possesses good filtering characteristics and does not retard the passage of steam into the pack-

age. Unbleached muslin is stronger than the bleached muslin.

ii. Canvas, because it is closely woven, retards the passage of steam and should not be used.

iii. Cellophane is impervious to steam and should not ordinarily be used. Certain small articles may be autoclaved in cellophane bags, if moisture is present inside the cellophane bag which is converted to steam during the sterilizing process.

iv. Paper may be used, but its permeability should be determined as well as its protective qualities. Large packs should not be wrapped in paper because the paper may become brittle after autoclaving. Holes or cracks in the paper may not be visible and this may allow contamination.

v. There are many methods of securing bundles for sterilization. Clips, pins, and staples should not be used, since they may tear the fabric or paper and contaminate the contents. They also tend to cause too tight wrapping of the pack.

String, rope, strong cord, cotton tape, and pressure sensitive tape can be satisfactorily used in securing the packages and bundles.

vi. Autoclave or pressure tape, in addition to fastening packages, is also of value to indicate that the package has been in the autoclave. It is not an indication that the contents are sterile.

vii. Different types of materials, such as basins and fabrics, should not be included in the same package for sterilizing.

viii. The method of packaging should be such that sterility can be maintained during storage.

(7) Loading the Autoclave

(a) Arrangement

i. Packs should be arranged to present the least possible resistance of the passage of steam through the load.

ii. Packs should rest on edge in loose contact with each other.

iii. Contents should be arranged in sterilizer, so that air will not be trapped.

iv. Utensils, jars or containers should be arranged in the sterilizer on their sides, so as not to trap air.

(b) Autoclave should not be overloaded.

(8) Drying of Load.

(a) A minimum drying period of 15 minutes should be established for packs and wrapped supplies, although it may take as long as 30 minutes to adequately dry the load. The directions for operating the specific autoclave should be followed. Usually, the drain and the chamber is closed. The vacuum valve is opened and the valve on the air inlet is opened to restore the interior to atmospheric pressure and to dry and cool the load. It should be allowed to cool before placing on cold surfaces to prevent sweating.

e. Recording Thermometer:

Recording thermometer, with bulb in the discharge line, should be installed in every autoclave. It is a practical detector of faulty sterilization, and provides an excellent method of maintaining daily chart records and shows that definite standards of time and temperature are being maintained. Records shall be kept at least one year. Graph records should be marked with date, year and time, and should designate the specific autoclave which it represents, if there is more than one autoclave.

f. Sterilization Indicators:

Sterilization indicators, such as the chemical ones commonly used, can show that the load in the autoclave has been subjected to the sterilizing process and as a result, the indicator has reacted. The reaction of the indicators does not necessarily assure sterility. While indicators have their advantages, it has been found that some will react, even though the time-temperature ratio is inadequate for sterilization.

If indicators are to be used, the indicator

resistance of the organisms and the number of organisms in the test sample of the culture should be known. Commercially prepared cultures are available or they may be grown in the hospital laboratory. The test culture should be placed in the densest and largest pack and the pack should be placed in the lower front part of the sterilizer, in a full load. It is also a good policy to place one of the packs containing a culture in the upper back part of the chamber.

h. Length of Sterility:

The length of time which autoclaved packs and articles can be considered sterile depends on packaging, type of storage area, and amount of handling. Once properly packaged and sterilized, packages may be stored indefinitely, if kept in dust-free and moisture-free areas. Such packages should be handled and moved as little as possible. It is advisable that tests be made to determine the length of time such packs retain sterility. A definite procedure, such as every four or six weeks for resterilization, should be adopted. There is evidence that for most hospitals it is possible to keep safely or to store properly packaged articles for at least four weeks after sterilization. There is no point in carrying out a resterilization at the end of one or two weeks, as has been the practice in many hospitals, unless it is necessary. Resterilization should involve a complete disassembling of the autoclaved pack. The wrappers and other linen should be laundered before reautoclaving. It is a good practice to place seldom used sterile packs in a polyethylene bag or wrapper for periods which exceed two weeks. Packs should be dated in order to determine the expiration date, if a policy is established for tearing down and reautoclaving. Different colored tape may also be used and the colors rotated on a schedule basis.

i. Mainteance of Sterilizing Equipment:

(1) Daily maintenance should consist of cleaning the drain screen in the chamber and changing the recording thermometer graph. Regular weekly cleaning should include the inside of the sterilizer and the flushing of the chamber drain line.

(2) A preventive maintenance program should be adopted in order to maintain sterilizers in good operating condition.

(3) Sterilization equipment is complex and the maintenance program shall be under supervision of competent and professional personnel. Manufacturers' directions should be followed.

j. Uses of "'Steam Under Pressure" Process:

(1) Supplies in Operating Room

(a) Surgical Packs—(fabrics)

The size of the pack should not exceed 12″ x 12″ x 20″. Two layers of unbleached muslin should be used as a wrapper. Each pack should be arranged so that its use is facilitated when opened. Care should be taken that the materials are arranged to promote rapid and complete permeation of steam through the mass. Packs should not be wrapped too tightly. They may be tied with strong cord or secured with tape. Other packs containing single items, such as towels or gowns, do not offer as much resistance to steam, but the same care should be taken to assure effectiveness of the process. Basins and other metal articles should not be included in the same pack as fabrics. Each pack should be dated.

(b) Surgical Instruments

Surgical instruments must be clean and free from grease and oil before sterilization. While "sharps" may be sterilized by "steam under pressure," sterilization by dry heat to preserve the cutting edges of these instruments is usually considered the preferred method.

i. Routine Surgical Instrument Trays: Trays should have perforated bottoms to permit circulation of air. All jointed instruments should be open to permit contact of steam. Exposure period for sterilization is 15 minutes at 121°C. (250°F.), or 7 minutes at 132°C. (270°F.). If trays are to be stored, they should be wrapped in two thicknesses of muslin wrappers and time of exposure increased to 30 minutes at 121°C. (250°F.).

ii. Emergency Sterilization of Instruments: Emergency sterilization should only be resorted to when it is necessary to sterilize one or very few instruments for immediate use. Sterilization for this purpose can be accomplished by the use of a "high speed" instrument sterilizer which is specially designed to operate at a temperature of 132°C. (270°F.) for 3 minutes. For this type of sterilization, instruments should not be wrapped. Only a few instruments should

be placed in any one load for this procedure.

(c) Surgical Dressing Drums

Metal dressing drums for sterile towels, dressings, sponges, cotton balls, etc., should not be used. The size of the drums makes sterilization difficult and the likelihood of the contents becoming contaminated with the repeated opening of the drums, makes their use hazardous.

(d) Hand Brushes

The type of bristles of brushes determines the method of sterilization. Synthetic and vegetable fiber brushes may be sterilized by steam under pressure. Exposure period for sterilization is 15 minutes at 121°C. (250°F.)

Hog bristle brushes do not withstand autoclaving and their use is not recommended.

(e) Sutures

The type of suture material determines the method of sterilization. Silk, nylon and cotton may be sterilized by steam under pressure. The exposure period for sterilization is 15 minutes at 121°C. (250°F.).

Most sutures used in hospitals are prepackaged and are sterile when purchased so sterilization need not be performed by the hospital.

(2) Supplies of Sterile Central Supply

(a) Syringes

Dry heat is the best method of sterilizing syringes, although sterilization by steam under pressure is still common practice and is satisfactory.

Syringes should be packed individually and the barrel should be separated from the plunger prior to sterilization to assure contact of all surfaces with steam. Syringes may be packaged in muslin or satisfactory paper envelopes or bags. The exposure period for sterilization is 30 minutes at 121°C. (250°F.).

(b) Needles

The preferred method of sterilizing needles is by dry heat. If autoclaving process is employed, needles should have some residual moisture in the cannula at the time they are placed in the sterilizer. Needles should be autoclaved without stylets. Needles may be autoclaved in satisfactory paper envelopes, in test tubes or in constricted glass tubes. If placed in glass tubes, some type of covering should be securely placed over the open end. Permeable paper or a double thickness of muslin is satisfactory, but cotton plugs should not be used. The tubes should be placed on their sides in the sterilizer to facilitate air removal and inflow of steam. Exposure time for sterilization is 30 minutes at 121°C. (250° F.).

(c) Rubber Goods

It is not possible for steam to penetrate rubber, so all surfaces must be freely exposed to steam during the sterilization process. Rubber deteriorates in air and steam mixtures. Care must be taken to be certain that air is removed from autoclave as well as that there are no air pockets retained in the material to be sterilized. Rubber goods should be placed in the upper two-thirds of the sterilizer to prevent residual air from coming in contact with the rubber goods.

i. Rubber Gloves

(aa) Air should be removed from the fingers of the gloves before packaging.

(bb) To insure air clearance, some material such as a band or tab of muslin or paper should be placed in folded portion of the cuff and into palm of glove.

(cc) Glove packages should be placed on edge with the thumbs up for proper sterilization and should be placed in the upper part of the chamber.

(dd) Gloves should be sterilized alone in the autoclave.

(ee) Muslin wrappers of billfold type

(bb) All tubing should be wrapped so that two surfaces of rubber do not touch.

(cc) Wrappers may be muslin, paper or cellophane, if the ends of the cellophane wrappers are left open.

(dd) Some types of rubber do not withstand this method of sterilization.

(ee) Cleaning substances containing chemicals which cause deterioration should be avoided. Oils, grease, benzine, cresol, etc., are examples which have this effect.

(ff) Exposure time for sterilization is 20 minutes at 121°C. (250°F.).

(d) Dressing Jars and Cans

Dressing jars and cans should not be used in hospitals. Contents may become contaminated each time the jar or can is opened. The small one-use individually wrapped packages are preferable.

If jars or cans must be used to contain sterile supplies, the contents should be packed loosely. They should be placed on their sides with the lids ajar. This allows the air to drain out and to be replaced by steam. The density of the supplies within the container should be limited. Exposure period for sterilization is 30 minutes at 121°C. (250°F.).

(e) Transfer Forceps and Container

Forceps used to transfer sterile items from one location to another should be washed with a detergent and then sterilized by exposure to steam under pressure for 20 minutes at 121°C. (250°F.), either wrapped or unwrapped. The container in which the forceps are stored should also be sterilized in the same manner. Even though the forceps are retained in a disinfectant solution, there is no assurance that sterility is being maintained. Eliminating the need for transfer forceps is recommended wherever possible. If transfer forceps are used, the transfer forceps and the container should be sterilized daily.

(f) Utensils and Glassware

Basins and utensils should be wrapped separately or separated with a porous material, such as gauze, if placed in the same pack. They should be placed on their sides in the autoclave so that air will not be trapped in any of the containers.

Glass articles should be protected from breakage. Exposure time for sterilization of utensils and glassware is 15 minutes at 121°C. (250°F.).

(g) Solutions

The size, shape, thickness and heat conductivity of the container holding the solution influences the time required for sterilization. The length of time required to heat all of the solution to sterilizing temperature determines the exposure period. If self-venting closures on containers are used, they may be left on during the sterilizing process; otherwise, they should be left open or loosely stoppered. Pyrex glass or the equivalent should be used for containers. Flasks should not be overfilled. Exposure time for a 1000 cc flask is 30 mintues at 121°C. (250°F.), for sterilization. A flask of smaller capacity, such as a 250 cc flask, may be adequately autoclaved in 20 minutes at 121°C. (250°F.). A flask of larger capacity, such as a 2000 cc flask, can be autoclaved in 45 minutes at 121°C. (250°F.). The exhaust on the autoclave should not be applied after completion of the autoclaving process. The pressure should be allowed to return to normal without applying exhaust.

(3) Supplies in Delivery Room

The same principles of sterilization apply here as in the operating room.

(4) Supplies in Laboratory

(a) Laboratory Media

When it is necessary to sterilize media for laboratory use, the composition of the media and type of container will determine the method of sterilization. Exposure period for sterilization, if it is to be autoclaved, is 20 minutes at 121°C. (250°F.).

(b) Laboratory Glassware

Laboratory supplies which are contaminated can best be decontaminated by exposure to steam under pressure for 20 minutes at 121°C. (250°F.), followed by mechanical cleaning.

Dry heat is the preferred method of sterilization of clean glassware when actual sterility is desired. This would include petri dishes, culture tubes, etc.

(c) Syringes and Needles

The same methods apply as in Central Sterile Supply.

(5) Housekeeping Equipment

(a) Mattresses and Pillows

When sterilization of a mattress or a pillow is required, particularly if the inside is considered a reservoir of infection, autoclaving is possible. It requires large sterilizers for the process and it may cause staining. Mattress and pillow covers also tend to deteriorate rapidly, if autoclaved frequently. Exposure period for sterilization is 30 minutes at 121°C. (250°F.). Other methods, such as exposure to ethylene oxide, is preferred to sterilization by steam under pressure, if it is available.

(6) Nursery Supplies

(a) Nursery Packs

Nursery linen, such as diapers, gowns, blankets, etc., are usually autoclaved before use. They should be made into individual packs or bundles, and autoclaved for use of each baby. Wrappers may be made of muslin or of paper. Bundles should be loosely wrapped.

(b) Individual Bassinet Equipment

Individual infant's equipment including safety pins, cotton, infant linen, diapers, etc. should be autoclaved. Exposure period for sterilization is 30 minutes at 121°C. (250°F.).

(c) Transfer Forceps and Container

Equipment for special treatments which must be sterile should be handled in the same manner and be in accord with procedures of Central Sterile Supply.

(7) Formula Room

(a) Contaminated formula equipment, such as formula bottles, bottle carriers, nipples and nipple covers, after mechanical cleaning, should be sterilized by exposure to steam under pressure for 15 minutes at 121°C (250°F.).

(b) When the "steam under pressure" method of formula preparation is employed, the completely assembled formula units should be autoclaved at 110°–111°C. (230°–232°F.), at 7 pounds pressure for 10 minutes or 121°C. (250°F.) at 15 pounds pressure for 5 minutes. The first of the two is preferable.

(8) Bedside Equipment

Bedside equipment, such as washbasins, mouthwash cups, bedpans and urinals, if sterilized by autoclaving, should be treated as other utensils and should have an exposure period of 15 minutes at 121°C. (250°F.).

k. Water sterilization

(1) Sterilizers which are specifically for the sterilization of water are reservoirs equipped with a source of heat (electric, gas, steam) and, except for the old types, have automatic pressure regulators. Each tank is equipped with an individual, self-sterilizing combination water and air filter which is controlled by a single valve.

The difficulty encountered in using the water sterilizers for sterilization of water is in maintaining sterility of the water following the sterilization process. There is also the possibility that faulty mechanics may interfere with the sterilizing process itself.

(a) Limitations of Water Sterilizers

i. The draw-off faucet becomes contaminated and thereby contaminates the sterile water as it is drawn from the sterilizer, unless some method of sterilizing the faucet is employed. It is difficult to sterilize the faucet.

ii. Air filter may be ineffective.

iii. Cooling coil in the cold tank may have a slow leak, thereby contaminating the sterile water.

iv. Leaky valves will permit unsterile water to enter sterile reservoirs.

v. Drainage connections may be piped direct to the waste line.

vi. The inside of the side arm gauge glass may be contaminated and there may be no provision to sterilize it.

(b) Factors to be considered in the use of Water Sterilizers

i. Water should not be regarded as sterile for more than 8–12 hours.

ii. Periodic checks for the performance of the sterilizer should be made.

iii. At end of sterilization period, the drain-off faucet should be thoroughly flushed.

iv. The sterilized water is not distilled and will contain chemical impurities which makes it unsafe for parenteral solutions.

v. There are many types of water sterilizers and the manufacturers' directions of each type must be followed.

(2) The individual flask technique, whereby the water is autoclaved in hermetically sealed flasks, is gradually becoming the method of choice. Water is not difficult to sterilize and when handled by the flask method, sterility can

always be assured. The method of sterilization of the individual flasks is the same as for any other types of aqueous solutions.

2. **Flowing Steam.** If steam is generated or held in a chamber under atmospheric pressure, it is said to be free flowing or streaming steam. The temperature cannot exceed that of boiling water. It is not usually considered as effective as boiling and can only be considered to disinfect, not sterilize. Whenever steam under pressure is available and possible, it should be used in preference to this method.

The Arnold sterilizer, not commonly used, disinfects by flowing steam. Its use is limited to small articles and packages. This method of disinfection should be discouraged.

a. Limitations

Flowing steam has the same limitations and may be less effective than boiling water. It cannot be relied on to sterilize. It is the least reliable of the physical methods of disinfection.

b. Uses

(1) The Arnold sterilizer may be used in the absence of "steam under pressure" for destroying vegetative organisms in small packages and for some materials, such as bottled liquids. It should not be used for hospital supplies.

(2) Laboratory media may be treated to this method in the absence of steam under pressure, but the method is less certain and is rarely used.

c. Period of Exposure

The minimum period for disinfection by this method is thirty (30) minutes after the steam begins to condense and drips back into the reservoir of the container from which it originally came.

3. **Boiling.** The application of heat to water at atmospheric pressure which brings the temperature of the water to the boiling point is considered a method of disinfection. It is no longer considered a method of sterilization, since the maximum temperature which can be reached is 100°C. (212°F.) or less, depending on altitude. Even with an extended lengthy exposure, resistant spores and viruses may withstand this temperature. It is a much less exacting procedure than sterilization under pressure and, therefore, should not be used where steam under pressure is available. The margin of safety with the use of the autoclave or sterilization by steam under pressure is greater, the time required for autoclaving is less and most objects withstand autoclaving better than boiling.

For disinfection, boiling is fairly satisfactory, because it will destroy all vegetative organisms and those which cause most communicable diseases. It should *never* be relied upon as a sterilization process.

a. Types of Equipment

(1) The so-called boiling water "sterilizer" is a metal container which is connected with the water supply and furnished with a gas, electric, or steam heating unit. It usually has a drain pipe connected to the plumbing system.

(2) A boiler, large container or kettle may be substituted for the boiling water sterilizer. It is regulated by the heat under it and the same principles apply to it as the boiling water sterilizer.

b. Limitations of Boiling Method

(1) The result of this process is disinfection and not sterilization, because of the low maximum temperature which can be reached at atmospheric pressure. The range of temperature of this method is suitable for the destruction of vegetative organisms, but cannot be relied on to destroy all bacterial life.

(2) Altitude affects the boiling point of water. The highest temperature that can be reached is 100°C. (212°F.) at sea level. At higher altitudes, the boiling point is decreased, thereby decreasing the effectiveness of the process.

(3) If the boiling water sterilizer is connected to the plumbing system, contamination of the contents of the sterilizer may occur, because of faulty plumbing connections.

The installation of this type of equipment should be in conformance with plumbing codes. Installed equipment should be properly vented.

c. Factors Affecting Efficiency of the Process

(1) The hydrogen ion concentration of the water affects the bactericidal efficiency. Addition of an alkali, such as sodium carbonate (sal soda) to make a two percent solution, or sodium hydroxide (caustic soda) to make a one-tenth percent solution, increases the disinfecting power of the water. The minimum time for safe dis-

infection can be reduced with the addition of such an alkali.

(2) All articles to be disinfected must be completely submerged during the boiling process. Air pockets which result from containers being placed upright may produce faulty disinfection in that the bacteria are protected from the destructive action of the moist heat.

(3) It is important that the heat be regulated to apply the amount of heat which will cause the water to boil rapidly enough to reach the maximum temperature. This is a moderate boiling condition, beyond a simmer, and not too vigorous as to boil violently, and producing dense clouds of steam in the room.

A thermometer on the sterilizer does make it possible to know when the maximum temperature has been reached. It might then be possible to regulate the heat mechanism in order to maintain the desired temperature.

(4) Scale formation of inorganic salts which are deposited on the articles in the water and on the inside of the sterilizer may be prevented or reduced by:

(a) Wrapping the objects in gauze or some other material before placing in the container

(b) Frequent draining of the container

(c) Avoiding too vigorous boiling

(d) Boiling the water before placing the objects in the container

(e) Use of a water softener

(5) Objects which have been disinfected should be removed from the water as soon as the process is completed. If allowed to remain in the water, they will become contaminated as the steam condenses.

(6) The sterilizer must be clean and free from oils and grease. Such substances prevent moist heat from contacting bacteria, thereby protecting them against effective disinfection.

(7) Objects to be disinfected must also be clean before exposing them to the boiling water, because dirt, grease or oils prevent the moist heat from contacting the bacteria.

d. Period of exposure

The safe minimum period for disinfection in boiling water 100°C. (212°F.) at sea level, is 30 minutes. If the hydrogen ion concentration is decreased by the addition of alkali, the period of exposure can be safely decreased. At higher altitudes, the exposure periods must be increased.

e. Uses of boiling water for disinfection

These should be limited to the following:

(1) Surgical Instruments

As already stated, the boiling water process is one of disinfection and not of sterilization. Therefore, this method should not be used in preoperative preparation of surgical instruments or for any purpose where sterile surgical instruments are desired.

(2) Bedside Utensils

The boiling process should be used for *disinfection only* and the exposure period should be 30 minutes. Utensils should be thoroughly cleaned, should be completely submerged during the process and should not be permitted to remain in the water after the completion of the process.

(a) After patient's discharge

After patient's discharge from hospital, the bedside utensils may be disinfected by boiling, although sterilization by steam under pressure is preferable.

(b) Contaminated utensils

After discharge of patient with communicable disease, utensils may be disinfected by this process. If hospital routine requires autoclaving, contaminated bedside equipment, after being cleaned, may be autoclaved instead of boiling. To prevent the spread of infection, contaminated utensils should not be removed from the nursing unit before being disinfected.

(3) Contaminated Dishes

Dishes and silver used by a patient with communicable disease may be disinfected by boiling 30 minutes. Proper dishwashing procedures are usually considered adequate for disinfecting dishes. The danger of spreading the infection lies in the handling of the contaminated dishes before they reach the dishwashing machine. A contaminated tray including dishes and silver may be placed in a water soluble plastic bag and closed with rubber band or string. The outside is clean and it can then be placed in the dishwasher without danger of spreading the infection.

(4) Syringes and Needles

Boiling syringes and needles in water will destroy nonspore-forming pathogenic organisms. The boiling method may be used to disinfect contaminated syringes, but must not be used if sterility is desired. Syringes which are

to be used for subcutaneous, intramuscular or intravenous injections should be sterilized by autoclaving or dry heat sterilization. The chemical composition of glass is also affected by boiling, making glass brittle and likely to break.

(5) Rubber Gloves

Gloves may be disinfected by boiling, although they lose tensile strength, elasticity, and shape. This is a fairly safe method of disinfecting contaminated gloves used in caring for a communicable disease or in the laboratory. The minimum boiling period is 30 minutes. This method is never used when sterility is desired.

(6) Formula Preparation and Equipment

(a) Formula bottles, caps and nipples from suspect, isolation, and pediatric nurseries should be disinfected by boiling for 10 minutes.

(b) When the nonpressure method of formula preparation is employed, the completely assembled formula unit (bottles with nipples and nipple covers), should be immersed in actively boiling water in a covered container. The water should be kept boiling for 25 minutes, being sure that the water does not touch the nipple covers.

B. Dry Heat

1. Dry Heat Sterilization. Dry heat sterilization is sometimes referred to as hot air sterilization. The process involves the absorption of heat from the surface of the substance which is being sterilized. The temperature and the time of exposure must be increased beyond the requirements of the processes which rely on moisture as well as heat. Heating of the contents takes place mainly by radiation from the walls and floor of the chamber or oven.

a. Types of hot air sterilizers

(1) Gravity Convection Type

The air circulates in accord with existing temperature differences between the various parts of the chamber. The heated air expands, rises, and displaces the cooler air, thus setting up a convection circulation. It is slower in heating and requires a longer time to reach sterilizing temperatures than with other methods. It should not be used when precise heating is required or where rapid heating is required.

(2) Mechanical Convection Type

Hot air is circulated through a chamber by means of a forced air blower. It is possible to control air velocity, direction of circulation, and heat intensity, thereby controlling temperature in the chamber.

(3) Use of Autoclave

Steam is applied only to the jacket of the ordinary pressure steam sterilizer. Unless a thermometer is placed in the jacket return line, the temperature cannot be accurately measured. It takes a long period of time, because the maximum temperature that can be attained is 121°C. (250°F.) when steam in jacket is kept at 15–17 pounds of pressure. The exposure period is a minimum of six hours, or preferably overnight. This process is not as reliable as a properly designed hot air sterilizer.

b. Factors of dry heat sterilization

(1) Temperature should be closely regulated.

(2) Sterilizer should not be overloaded.

(3) Some space should be allowed between articles in the sterilizer to promote penetration and permit free circulation of air.

(4) All articles exposed to dry heat sterilization must be clean of all organic material and must be free from traces of oil or grease.

(5) The characteristics of material, method of preparation of articles to be sterilized, packaging or wrapping, and loading of sterilizer are all factors which determine exposure periods and temperature. It is difficult to establish specific exposure periods and temperatures for all materials.

c. Limitations of use of dry heat sterilization

(1) When used at sufficiently high temperatures to assure sterilization, some fabrics and rubber goods deteriorate and are destroyed.

(2) Penetration is slow and difficult.

(3) Higher temperatures for longer exposure periods are required than are necessary when moisture is present.

(4) Dry heat method is difficult to control except in specially designed sterilizer.

(5) Temperature is likely to vary within the load being sterilized.

(6) While dry sterilization is best for anhydrous oils, greases, powders, etc., there is danger of decomposition and discoloration.

(7) The presence of organic matter interferes with sterilizing process. Articles which are to

be sterilized must be well cleaned and free from grease and oils.

d. Advantages of use of dry heat sterilization

(1) Dry heat does not erode ground glass surfaces so that this method may be successfully used on glass articles such as syringes, and other glassware.

(2) Dry heat does not have corrosive effect on sharp metal surfaces, so it is a satisfactory sterilizing agent for sharp cutting instruments, if exposed only for a reasonable length of time.

(3) Dry heat sterilization is satisfactory for anhydrous oils, greases, powders, etc.

e. Uses of dry heat sterilization

(1) Glassware, such as petri dishes, test tubes, empty flasks, medicine glasses, etc., may be sterilized by 60 minutes exposure at 160°C. (320°F.). They should be thoroughly washed, rinsed in distilled water and wrapped before being subjected to dry heat sterilization.

(2) Syringes

(a) Syringes should be thoroughly cleaned and dried. They should be wrapped in muslins, packaged in test tubes with muslin or paper covers, or put in paper bags with high bursting strength and controlled porosity which are especially made for this purpose.

(b) Syringes may be assembled or unassembled and needle may or may not be included in the package.

(c) Time of exposure should be 60 minutes at 160°C. (320°F.), if wrapped in muslin or if unwrapped with covered tip. If syringe is enclosed in test tube, exposure time should be increased to 75 minutes.

(3) Needles, hollow

Needles should be protected from mechanical dulling.

(a) Stylets should not be placed in needles.

(b) Needles may be included in packet with syringe, but point should be protected.

(c) Exposure time should be two hours at 160°C. (320°F.).

(4) Cutting Edge Instruments

Instruments should be clean, free from oil and grease and placed on a flat metal tray before being placed in the hot air sterilizer. Exposure of one hour at 160°C. (320°F.) is necessary. Too high temperatures will destroy cutting edge.

(5) Suture Needles

Suture needles may be threaded into gauze, wrapped in muslin and exposed to 160°C. (320°F.) for one hour.

(6) Powders

(a) Longer period of exposure is necessary, because of slow rate of heat transfer.

(b) Amount of powder in one package or container should be limited to small amounts, preferably for one use of application. It should be in flat container and depth should not exceed one-quarter inch.

(c) The decomposition temperature point should be known for the powder which is being sterilized. The temperature should not approach or exceed this decomposition point.

(d) Exposure period

zinc oxide powder 160°C. 320°F.) for 2 hours

sulfa powder 140°C. (285°F.) for 3 hours

(7) Oils and Nonaqueous Substances

(a) Oils and nonaqueous substances, since they cannot be penetrated by steam, can be better sterilized by dry heat than by autoclave. Long high heat periods in sterilization are required since steam does not penetrate the substance.

(b) The amount of substance should be as small as possible and the depth of the layer should be reduced to at least-one-quarter inch.

(c) Exposure period.

(1) Oils such as mineral oil, paraffin and petroleum jelly should be sterilized at 160°C. (320°F.) for two hours, if layer is kept to a one-quarter inch depth.

(2) Petrolatum gauze

Bandage gauze impregnated with petrolatum jelly should be placed in metal tray in layers not more than one-half inch deep and should be exposed for 2½ hours at 160°C. (320°F.). These items may also be purchased in small single-use size packages already sterile.

2. Charring. Charring or the actual destruction of the microorganism by burning, occurs when exposed to heat capable of burning for a period of not less than 20 seconds. This method is usually used in connection with moisture, such as with the use of cautery. The cautery when exposed to live tissue generates steam and burns

the tissue after the moisture is eliminated. Desiccation by the fulgurating needle is another example.

3. **Flaming.** Applying the actual flame to an object is a method of sterilization. It is most widely used in the laboratory for the sterilization of platinum loops. To be effective, the loop must be entirely heated until it glows.

The use of flaming in sterilizing instruments has little or no value except where it can be held in a naked flame without damage of dulling the edges of the instrument.

4. **Incineration.** Incineration is the process of burning and reducing substance to ashes, thereby destroying the substances as well as any living organisms which are contained in it.

a. Uses of incineration

Types of waste which are usually destroyed by this method are:

(1) Rubbish
(2) Refuse (organic and inorganic)
(3) Garbage

b. Factors

(1) Incinerators for hospital use are usually intended to cover a wide range of performance operating conditions. Refuse may vary and the kinds and proportions of solid and semi-solid wastes will vary, thus causing a wide variation in heat of combustion and the burning characteristics.

(2) Auxiliary firing by gas or oil is usually necessary to provide combustion, because of wide variety of kinds and type of refuse, garbage, etc.

(3) Incinerators are expected to burn the refuse to ashes without the emission of smoke, bad odors, fumes, ashes, charred materials, embers and sparks.

(4) Where pathological wastes are to be disposed of, it is essential that the incinerator provide the necessary heat to dispose of the pathological waste.

(5) In designing incinerators, the following should be considered:

(a) Burning rate
(b) Heat release
(c) Mixing velocities
(d) Settling velocities
(e) Flue and chimney velocities

CHEMICAL METHODS OF CLEANING AND DISINFECTION

When chemicals are employed to destroy organisms, the process should be called disinfection rather than sterilization. The absolute destruction of all organisms by any of the chemicals is uncertain and it is necessary to qualify the term "disinfection" by specifying the exact organisms which are being destroyed. Chemicals should be resorted to as a means of obtaining sterility *only* if a reliable method of sterilization is not available or possible. Many of the chemicals are more bacteriostatic than germicidal. Many chemical disinfectants destroy vegetative bacterial and fungal forms, but have no effect on spores. Tubercle bacilli are also resistant to some chemicals commonly used as disinfectants. Viruses seem to vary in their resistance, and while their ability to withstand chemicals is not clearly understood, it seems reasonable to say that some viruses are not destroyed by exposure to chemical disinfectants in the normally used concentrations.

It should be pointed out that many of the chemical disinfectants destroy certain kinds of vegetative bacteria and permit others to survive or even grow and multiply. In selecting chemical agents for disinfection in the hospital, it is important that each hospital establish a definite written plan for the use of these agents and that all personnel be oriented in the details of their use. Concentration, type of diluent, methods of application, and length of exposure are all factors to be considered in the use of these substances.

A. Factors Which Influence the Action of Chemical Agents

1. **Cleanliness of the Surface.** The cleanliness of the surface to be disinfected is important in determining the effective concentration of the germicide. The presence of organic substances such as pus, blood, or other secretions greatly interferes with the effectiveness of the chemical action. Absolute cleanliness of the surface to be disinfected is essential for reliable germicidal action. Any outer coating of the surface which is of protein nature may be coagulated by the germicide and prevent penetration of the chemical.

2. **Concentration.** It can usually be said that the stronger the solution, the more effective will

be its disinfectant action. While a strong solution will often kill organisms more quickly, it may be more irritating to the tissues and be injurious to textiles and materials. In such cases, the weaker solutions must be used.

3. **Time.** The time required for the different chemical agents to function effectively as disinfectants may vary from seconds to hours. In each case it is essential that the minimum time of exposure to a specific concentration of the chemical solution be known if disinfection is to be assured.

4. **Temperature.** Temperature may affect the efficiency of a disinfectant and should be considered when selecting a chemical agent.

5. **Noncorrosiveness and Destructive Characteristics.** Some chemical agents have a marked corrosive action on metal surfaces and are injurious to rubber and other substances.

6. **Type of Organism.*** Some organisms are more readily killed than others. Some types are particularly resistant to chemicals. It cannot be assumed that a chemical disinfectant is effective for all types of organisms. The specific action of the chemical agent on the organism must be known.

7. **Chemical Compatibility.** If a chemical disinfectant is used in conjunction with another substance, it is necessary to consider the compatibility of the two substances. Alkalinity, acidity, oxidation or reducing properties, etc. may adversely affect the action of the disinfectant.

B. Types of Chemical Disinfectants

1. **Alcohols.** The alcohols, particularly ethyl and isopropyl alcohol, are good disinfectants. They have a bactericidal rather than bacteriostatic action against vegetative forms of bacteria. Vegetative forms of organisms and tubercle bacilli are destroyed readily in a 70 to 90 percent concentration by weight. The destructive action of alcohol against spore forms is much less than against vegetative forms and the effectiveness of alcohol against viruses has not been well established. The alcohols are safe, relatively inexpensive and readily obtainable. They have a cleansing action. Alcohol acts quickly, evaporates readily and leaves no residue. It is believed that isopropyl alcohol has slightly greater bactericidal action than ethyl alcohol. It is inexpensive, nonpotable, tax-free, and is a somewhat better fat solvent than ethyl alcohol.

*See Appendix B, "Recommendations for Chemical Disinfection."

Any concentration between 70 and 92 percent by weight or between 80 and 95 percent by volume has high germicidal activity. Anything lower than 70 percent by weight or 80 percent by volume is inadequate, particularly, if there is any likelihood of contamination with body or tissue fluid. The addition of iodine to alcohol increases the effectiveness of the two substances, both in terms of necessary time of exposure and the number of bacteria killed.

Uses:

a. Skin disinfectant

An alcohol solution, 70 percent to 92 percent concentration by weight is an effective skin disinfectant. While it has no effect on spores, it does destroy vegetative organisms. The concentration of the solution determines the effectiveness, as well as friction, which may be applied to enhance the action. The time of exposure is also a factor.

b. Cleansing thermometers

(1) Combining equal parts of alcohol and green soap has been found to be an effective solution for washing thermometers.

(2) Clean thermometers are sometimes stored in an alcohol solution (70 percent by weight) containing one percent iodine.

(3) Thermometers may be stored dry, after being thoroughly washed.

c. Disinfection of instruments and needles

The use of an alcohol solution for disinfection of instruments and needles should be employed only when a reliable method of sterilization is not available.

d. Anaesthesia equipment

Some anaesthesia equipment will not withstand autoclaving, but can be successfully disinfected with alcohol. If other more effective methods are possible, this type of disinfection should not be used.

2. **Mercurials.** Although mercurials have been used in hospitals for many years, they have come to be regarded as poor germicides, and as chemical disinfectants, they are not recommended. While they are highly bacteriostatic, they cannot

be depended on to destroy all vegetative organisms and do not destroy sporulating organisms.

The inorganic mercurials are toxic and irritating to tissue, tend to precipitate proteins and have a corrosive action on metal.

The organic mercurials are less toxic, less irritating to tissue and do not corrode instruments, but are not believed to be any more effective than the inorganic substances.

3. Halogens

a. Iodine

Iodine is generally regarded as a good germicide and has received wide use in hospitals. Its action is dependent on the free iodine which is contained in or released from the compound in which it is contained. Experiments show that iodine is comparable with other bactericides and deserves a high rating among the most efficient disinfectants. It is reported that iodine possesses sporicidal and fungicidal efficiency and has some action on viruses.

Commonly Used Types of Iodine Solutions:

(1) Iodine tincture refers to a preparation containing 2 percent iodine, and 2.4 percent sodium iodide in diluted alcohol (the final alcohol content is 47 percent).

(2) Iodine solution refers to a water solution and has wide usage.

(3) An iodophor is a compound containing a combination of iodine and a solubilizing agent or carrier for the iodine. The iodine is slowly liberated when diluted with water. The iodophors are stable, relatively nonstaining on fabrics and tissues, nontoxic, nonodorous and retain all the desired antimicrobial activities of iodine. Some of these disinfectants have become general purpose disinfectants and are effective against viruses, fungi and bacteria, including the tubercle bacilli, if used in strong concentrations.

(4) Other iodine preparations, such as organic compounds containing iodine or containing free iodine, are used for specific purposes in hospitals.

Uses:

(a) Skin disinfection

i. Preoperative preparation of the skin. Iodine tincture is the solution most often used.

ii. Prior to insertion of needle into skin for:

(aa) Removal of fluid such as blood, spinal fluid, bone marrow and transudates

(bb) Administration of parenteral medication

(cc) Immunization

iii. Skin disorders

iv. Application to mucous membranes

v. Disinfection of hands

(b) Disinfection of instruments and other equipment including anaesthesia equipment

(c) Disinfection of catgut and other surgical suture materials

(d) Disinfection of clinical thermometers

(e) Disinfection of dishes and eating utensils

b. Chlorine

Chlorine as it appears in the hypochlorites and other organic compounds which liberate chlorine, is an important disinfectant in the hospital. The germicidal effect is dependent upon the release of hypochlorous acid. These chlorine compounds have germicidal effects upon bacteria and viruses. They are effective against spores only if the solution is neutral or slightly acid. The presence of organic material reduces the effectiveness of chlorine disinfectants. Acid-fast bacteria, such as tubercle bacilli, are not destroyed by these chlorine compounds. They are irritating to tissue, corrode metal and are injurious to rubber.

Uses:

(1) Disinfection of toilets, lavatories and bathtubs

(2) Disinfection of floors

(3) Disinfection and bleaching of linen

(4) Dishwashing

c. Bromine

Synthetic chemical substances with a bromal derivative have been developed as effective germicides. While their effectiveness against spores and viruses has not been well established, they are germicidal for some of the presently antibiotic resistant strains of organisms. They are used both in solution for washing surfaces and in laundering fabrics as well as an aerosol spray for surfaces.

Uses:

(1) Laundry

(2) Surfaces (furniture, floors, walls, mattresses, bedsprings, etc.)

4. Phenols

a. Effectiveness of phenol

Phenol is effective against all vegetative bacteria when used in the correct concentration. It is less effective against spores and its ability as a virucide has not been established.

It is very toxic, is irritating to the skin and destroys tissues, if used in strong concentrations.

Its use has not been entirely abandoned, but it is not generally employed in hospitals.

b. Phenolic derivative and synthetic phenols

During recent years, phenolic derivative and synthetic phenolics have come into use. They generally have the same advantages as phenols without some of the disadvantages. They are odorless and have a low toxicity. In the correct concentrations, they are effective against vegetative bacteria, but are not effective against spores.

Uses:

(1) Floors, walls and furniture
(2) Dishes and utensils
(3) Laboratory glassware
(4) Disinfection of instruments, syringes and needles

c. Cresol

Cresols are similar to the phenols in their action on vegetative organisms. The chief disadvantage is their disagreeable odor. They are not effective against spores.

d. Hexachlorophene

Hexachlorophene, a bis-phenol, retains its bacterial potency when combined with soap and detergents. Its action is slow and its degerming action is attributed to a film which is deposited and left on the surface to which it is applied. It is only slightly soluble in water, but is soluble in alcohol, acetone, etc.

Hexachlorophene's greatest usefulness is as a handscrub, if used repeatedly. Combined with soap, it has proved to be an excellent agent for the surgeon, intern and nurse in surgery who scrub routinely. It is also effective in the newborn nursery, where repeated handwashings are essential in the everyday routine of infant care. It is sometimes used in bathing infants.

Uses: Skin disinfectant

(1) Preoperative preparation
(2) Newborn infants
(3) Hand scrub
(a) Surgical
(b) Nursery personnel
(c) Laboratory personnel
(d) Food handlers

5. Quaternary Ammonium Compounds. This group of compounds is used extensively for disinfection in hospitals, although there are some limitations and many organisms are not affected by the quaternary ammonium compounds. They are surface-active compounds and possess the useful property of lowering the surface tension of the solution. They are highly stable and non-irritating when used in recommended concentrations. They are effective in destroying ordinary vegetative organisms, but do not destroy tubercle bacilli, pseudomonas, proteus and other gram negative bacilli. Their effectiveness against viruses has been questioned and they cannot be depended on to destroy spores.

Ordinary soap and other surface-active anionic detergents interfere with the germicidal activity of these disinfectants; so, if soap or detergents have been used, they must be thoroughly rinsed before exposing the substances to the quaternary ammonium compounds. The presence of certain dissolved minerals such as calcium, magnesium and iron in the water to which these substances are added, also decreases the efficiency of these disinfectants.

Uses:

a. Surgical instruments
b. Furniture, floors
c. Dishwashing
d. Laundry

6. Detergents and Soaps. A detergent is defined as an agent which will aid in or cause the removal of unwanted or extraneous material from a particular surface. All cleaning agents are detergents, but may or may not be disinfectants. Bacteria are usually removed, however, whenever they are employed.

Soaps are compounds of fatty acids and soluble alkalis and in themselves are not disinfectants. When mixed with water, they remove dirt and surface bacteria which are loosely attached. Most detergents may be classified as alkaline, neutral or acid cleaners. Some are more effective than others for cleaning particular surfaces.

The process of cleaning with a detergent is really the exchange of a soiled surface condition for a clean surface plus a soiled detergent.

The effectiveness of a detergent is dependent upon the following factors:

- Kind of surface being cleaned
- Nature and amount of soil
- Composition and concentration of the detergent
- Time of exposure to the cleaning agent
- The hardness of the water
- pH of the cleaning solution
- The mechanical action used (scrubbing, rubbing, etc.)

Hospital Uses of Soaps and Detergents:

- Laundry
- Dishwashing
- Hard surfaces (walls, furnitures, floors, etc.)
- Handwashing (preoperative scrub and routine handwashing)
- Equipment, utensils, etc.

7. **Formalin.** Formaldehyde gas when placed in solution (40 gm. of the gas to 100 ml. of water) is known as formalin and has been widely used in hospitals as a disinfectant. It has been especially used in the disinfection of instruments, because it is effective against spores and does not corrode instruments or affect the cutting edge.

The U.S.P. solution contains 37 percent by weight of the gas in water. It is actively germicidal even at 5 percent and destroys spores. It is also effective in the presence of organic material. It is a powerful deodorant, has an objectionable smell, and is irritating to tissues. It coagulates proteins, so care must be taken to remove the formalin from instruments before being applied to tissues.

In the laboratory, formaldehyde has been extensively used for the inactivation of viruses in the preparation of vaccines.

GASEOUS STERILIZATION

Gaseous sterilization for use in hospitals is the result of a fairly new development. Fumigation, however, as a method of disinfecting enclosed air spaces has been employed for many years.

Until the recent development of gaseous sterilization for surgical dressings, instruments, linen, etc., heat and moisture was almost always applied in the sterilizing process. With the increasing use of materials which are sensitive to heat and moisture, gaseous sterilization has come into prominence and today it is considered an effective method of sterilization.

A. Ethylene Oxide

Sterilization occurs by exposure to the gas. The effectiveness is based on the gas itself and is not dependent on a great increase in temperature. It does not injure fine, delicate instruments or fabrics.

1. **Properties of Ethylene Oxide**

a. Extremely active.

b. Pleasant etheral odor.

c. Soluble in all proportions in water, alcohol, and ether.

d. Highly inflammable.

The vapors form an explosive mixture with air. It is made safe by the addition of an inactive gas such as carbon dioxide, freon, or nitrogen.

e. Irritating to the skin and mucous membranes.

Skin eruptions may result from contact with the substance or materials in which the vapor is absorbed.

f. Moderately toxic.

It must not be inhaled.

2. **Sterilizing Equipment.** The type of equipment necessary for gaseous sterilization consists of a closed sterilizing chamber with automatic controls for the complete cycle of the process. Exposure time, temperature, and humidity controls are set after loading and are automatically controlled until the completion of the cycle.

3. **Factors Affecting Sterilization With Ethylene Oxide**

a. Humidity

Humidity should be maintained in the range of 25 percent to 50 percent for the greatest effectiveness.

b. Temperature

The exposure period can be reduced with a rise in temperature. Temperature is maintained in the range of 38°–60°C. (100°–140°F.).

c. Concentration

The concentration of the gas is a factor affecting the exposure period. Concentration is considered effective within the margin of 450 mg. and 760 mg. per liter of chamber space.

d. Exposure period

The length of the exposure period depends on temperature and concentration.

4. Advantages of Ethylene Oxide Sterilization

It is effective against all types of organisms.

It can be used on objects which would be damaged by heat or moisture.

It has the ability to diffuse and easily penetrate through a mass of dry material.

It is not necessary to attain high degree of humidity or temperature.

It is easily obtainable.

High pressures are not required.

5. Disadvantages of Ethylene Oxide Sterilization

Installation of the necessary equipment is expensive and if large items are to be sterilized, the necessary equipment is highly expensive and takes much space.

It is toxic both through inhalation and vesicant action on skin.

Process is lengthy and exposure time is long.

Sterilized objects may absorb ethylene oxide during the process. It is necessary to allow time for gas to be dissipated before being used.*

6. Uses of Ethylene Oxide Sterilization

There are many articles used in hospitals which are damaged by heat and moisture and which can be effectively sterilized by this method. While ethylene oxide gas is highly penetrating, there are materials in which the rate of penetration is slowed down considerably, due to the nature of the materials or how they are packaged.

The following types of articles used in hospitals can be effectively sterilized.

Rubber goods
Catheters
Delicate surgical instruments
Needles and syringes
Electrical equipment
Plastic materials
Telescopic instruments
Bedding and blankets
Mattresses and pillows
Bassinets
Anaesthesia equipment
Heart-lung oxygenator
Special laboratory glassware

Because the use of ethylene oxide as a sterilizing agent is fairly new in hospitals, it is essential that it be understood and that the conditions named above are controlled in order to insure an effective sterilization process. Manufacturers' instructions for the operation of gaseous sterilizing equipment should be closely followed.

B. Formaldehyde Gas

Formaldehyde gas has been known for years as a bactericidal agent. While not used as a terminal fumigant in hospitals as much as formerly, it is still regarded as a fairly effective method of disinfection. It has also been used to disinfect certain types of surgical instruments or medical equipment in small, specially designed cabinets. It is sometimes used for disinfecting hospital bedding. Formaldehyde disinfection is obtained by vaporizing formalin and maintaining a relative humidity of at least 70 percent and a temperature of at least 20°C. Vegetative bacteria are killed within an hour or two, although a longer period is required for bacterial spores.

There are so many disadvantages to this method of disinfecting that it is gradually being replaced by other more effective and reliable methods.

1. Advantages of Formaldehyde Gas Sterilization

It kills all bacteria.

It is fairly economical.

2. Disadvantages of Formaldehyde Gas

It lacks the ability to penetrate.

It lacks the ability to diffuse evenly to all surfaces.

It has an irritating odor.

It requires high humidity and high temperatures.

Long periods of exposure are required.

It is difficult to remove the residual formaldehyde which remains after exposure.

C. Glycol

Glycols, usually triethylene or propylene, used as vapors or aerosols, have proved to be bactericidal when applied in an enclosed area. The use of glycols for this purpose is still somewhat experimental and has not been generally recommended for widespread use.

*A minimum of 48 hours dissipation time is suggested for mattresses and 72 hours for rubber and plastic goods, to eliminate any chance of burning patients' skin after direct contact.

The use of this method of destroying organisms promises to become practical and to be standardized. It is rapid acting and is uniformly disseminated. It is not toxic and there is no odor. It does not cause corrosion on metal surfaces.

The chief disadvantage is the lack of a practical method of vaporization and maintenance of an adequate and even distribution of bactericidal concentration of vapor. It collects on surfaces, thereby reducing the saturation of the vapor in the air.

D. Beta-Propiolactone Vapor

This substance has recently been described as one capable of destroying all micro-organisms with which it comes in contact. It is said to have limited penetrating properties. Its effectiveness is dependent on the concentration of the vapor and the relative humidity. Its effect is more rapid than ethylene oxide. It is not flammable. In experimental use, it has been demonstrated that large spaces can be sterilized.

It has been used only in the laboratory for testing purposes, but it may offer real possibilities in the hospital for sterilization in the future.

E. Other Gases

Other gases which have been used as bactericidal agents but have found little or no use in hospitals are:

- Sulfur dioxide
- Chlorine
- Ozone
- Methyl bromide
- Chloropicrin

RECOMMENDATIONS FOR CHEMICAL DISINFECTION OF MEDICAL AND SURGICAL MATERIALS*

Earle H. Spaulding, Ph. D.

Which germicidal solution to use and how to use it is greatly influenced by the types of microorganisms to be destroyed. For the purposes of disinfection bacteria fall into three types: (a) ordinary (vegetative) bacteria such as staphylococci; (b) tubercle bacilli; and (c) spores. *Provided prior cleansing is thorough*, satisfactory disinfection can be obtained as follows:

A. Vegetative Bacteria and Fungi

1. *General comment.*—Many germicides fulfill these easy requirements. Some of them are: (a) 80 to 90 percent ethyl or isopropyl alcohol*; (b) strong formaldehyde-alcohol solutions* of the Bard-Parker Germicide type; (c) cationic quaternary ammonium solutions* such as Zephiran*, 1:750 aqueous; (d) 1 percent phenolic germicides such as Amphyl**, O-syl**, San Pheno X, and Staphene; (e) 2 percent phenolic germicide-cleansers such as Di-crobe, Tergisyl, and Vesphene; (f) iodophors such as Hi-Sine*, Ioclide*, Virac*, and Wescodyne*, 75 parts per million available iodine; (g) 2 percent activated glutaraldehyde, aqueous (Cidex).
2. *Smooth, hard surfaced objects.*—Five minutes' exposure to any of the solutions in A.1. If the object is metal, add 0.2 percent sodium nitrite to solutions marked *, and 0.5 percent sodium bicarbonate to solutions marked ** to prevent rusting.
3. *Rubber tubing, "shellac" and "web" catheters.*—Flush by syringing with solution A.1. (c), (d), (f), or (g), and immerse in the same solution for 10 minutes. Follow by a sterile water flush and rinse.
4. *Polyethylene tubing.*—Same as A.3. Solutions A.1 (a) and (b) are very satisfactory if tubing is clean.
5. *Lensed instruments.*—Cleanse and immerse for 5 minutes in A.1(g). Rinse with sterile water.
6. *Hypodermic needles and syringes.*—Until more is known about the chemical resistance of the hepatitis viruses the only safe method is heat sterilization.
7. *Hinged instruments.*—Cleansing must be particularly thorough. Then immerse for 20 minutes in any of the solutions in A.1. except (e). See A.2. for comment on rust prevention.
8. *Floors and walls.*—A disinfectant is no substitute for soap and water. Use one of the phenolic germicide-cleansers in A.1(e), or a good detergent scrub followed by an A.1(d) solution.

*The large number of tests upon which these recommendations are based were carried out by several assistants, especially Mrs. Ellen Emmons.

I wish to acknowledge the valuable assistance of: Mildren L. Guzara, R.N., B.S., Supervisor of Operating Rooms, Temple University Medical Center; and of (Mrs.) Vernita Cantlin, R.N., M.S.

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The compounds evaluated by Dr. Spaulding and his coworkers are only a small proportion of those available. The inclusion of information for proprietary materials does not reflect any endorsement by the Public Health Service or the U.S. Department of Health, Education, and Welfare, but represents only the evaluation of some typical compounds by one recognized authority in the field of hospital disinfection.

Evaluation of Germicides (Bacteria only)

Earle H. Spaulding, Ph. D.

Liquid	General usefulness as—		Effectiveness against—		Other properties
	Disinfectants	Antiseptics	TBC	Spores	
Mercurial compounds	None	Poor	None	None	Static only; inactive by organic matter; bland.
Phenolic compounds	Good	Poor	Good	Poor	Bad odor; irritating; not inactive by organic matter or soap; stable.
Quaternary ammonium compounds ("Quats").	Good	Good	None	None	Neutral by soap; relatively nontoxic; odorless, absorbed by gauze and fabrics.
Chlorine compounds	Good [1]	Fair	Fair [1]	Fair [1]	Inactive by organic matter; corrosive.
Iodine and iodophors	Good	Good	Good [4]	Poor [4]	Staining temporary; relatively nontoxic; corrosive.
Alcohols	Good [2]	Very good.[2]	Very good.[2]	None	Volatile; strong concentrate required; rapidly cidal; inactive by organic matter.
Formaldehyde	Fair	None	Good [3]	Fair [3]	Toxic; irritating fumes.
Glutaraldehyde	Good	None	Good	Good	Low protein coagulability; aqueous solution useful for lens instruments and rubber articles. Unstable; corrodes metal on 24 hours' exposure. Toxic.
Hexachlorophene	Fair	Good	None	None	Slow acting; not neutral by soap; H_2O, insoluble; alcohol soluble; inactive by organic matter.
Combinations:					
Iodine-alcohol	Fair	Very good.	Very good.	None	Stains fabrics.
Formaldehyde alcohol	Good [3]	None	Very good.[3]	Good [3]	Toxic; irritating fumes; volatile.
Gas:					
Ethylene oxide	Special	None	Good	Good	Poisonous; expensive; penetrating.
Beta propiolactone	Special	None	Good	Very good.	Vesicant; carcinogenic; expensive; unstable.

[1] 4 to 5 percent concentrate.
[2] 70 to 90 percent concentrate.
[3] 5 to 8 percent formaledhyde (12 to 20 percent formalin).
[4] 450 or more ppm. available I_2.

9. *Furniture and plastic bedding covers.*—Use one of the solutions in A.1 (d) or (f).

B. Organisms in A., Plus Tubercle Bacillus

1. *General comment.*—The list of acceptable solutions is not long: (a) 80 to 90 percent ethyl or isopropyl alcohol; (b) strong formaldehyde-alcohol solutions of the Bard-Parker Germicide type; (c) the phenolic germicide in A.1(d) in 2 percent final concentration; (d) the phenolic germicide-cleansers in A.1(e) but in 4 percent final concentration; (e) a strong concentration (450 ppm. of available iodine) of one of the iodophors in A.1(f); (f) 2 percent activated glutaraldehyde.
2. *Smooth, hard-surfaced objects.*—Five minutes' exposure to B.1 (b) and (f); 10 minutes' for the other solutions in B.1.
3. *Rubber tubing, "shellac" and "web" catheters.*—Flush by syringing with B.1 (c), (e) or (f). Then immerse in same solution for 10 minutes. Rinse and flush thoroughly with sterile water.
4. *Polyethylene tubing.*—Use B.1(f) solution as in B.3 or flush by syringing with B.1 (c) or (e), then rinse and flush with water, flush with solutions B.1 (a), (b) or (f) and immerse for 5 minutes.
5. *Lensed instruments.*—Cleanse and immerse in B.1(f).
6. *Hypodermic needles and syringes.*—See A.6.
7. *Hinged instruments.*—Cleansing must be particularly thorough. Then immerse for 20

minutes in one of the solutions under B.1. See A.2. for comment on rust prevention.

8. *Floors and walls.*—Thorough cleansing with a 4 percent solution of one of the germicide-cleansers in A.1(e).
9. *Furniture and plastic bedding covers.*—Use B.1 (c) or (e).

C. Organisms in A. and B. Plus Spores

1. *General comment.*—The only solutions that qualify as acceptable sporicides are: (a) strong formalin-alcohol solutions of the Bard-Parker Germicide type; (b) 2 percent activated glutaraldehyde (Cidex).
2. *Smooth, hard-surfaced objects.*—See C.1; at least 3 hours' exposure.
3. *Rubber tubing, "shellac" and "web" catheters.*—Flush with and immerse in solution C.1 (b) for at least 3 hours.
4. *Polyethylene tubing.*—same as C.3. or flush and rinse with B.1 (c) or (d), and then immerse for 3 hours in C.1(a).
5. *Lensed instruments.*—Use C.1(b) for 3 hours.
6. *Hypodermic needles and syringes.*—See A.6.
7. *Hinged instruments.*—Cleansing must be particularly thorough. Then immerse in a solution of the types mentioned in C.1. See A.2. for comment on rust prevention.
8. *Floors, walls, furniture, etc.*—The sporicides in C.1. are not applicable. Therefore spores must be removed mechanically by thorough cleansing.

SUPPLEMENTARY RECOMMENDATIONS

Transfer forceps.—A strong formaldehyde-alcohol solution of the Bard-Parker Germicide type in closed container.

Contaminated cases:

Instruments.—Soak in a solution in A.1. (c), (d), or (f) for 10 minutes. Cleanse sharps and follow procedure in C.2. Autoclave everything else that can be sterilized this way.

Furniture, floors, etc.—See A.8.

Oral thermometers.—Wash with soap and water; wipe dry and store in 80 to 90 percent ethyl alcohol containing 0.2 percent iodine.

Anaesthesia apparatus.—Two percent activated glutaraldehyde (Cidex).

VIRUSES*

Use 10 minutes exposure to 80 to 90 percent by volume ethyl alcohol formaldehyde-alcohol solution of the Bard-Parker Germicide type, 2 percent glutaraldehyde (Cidex), or an iodophor at 150 ppm. or more available iodine.

NOTE.—All articles which may carry hepatitis virus should be heat sterilized.

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*Based upon the tests and opinions of Dr. Morton Klein, Department of Microbiology, Temple University Medical Center, Philadelphia, Pa.